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THE WATER METER:

ITS DIFFICULTIES,

TYPES,

AND APPLICATIONS.

WALTER G. KENT.

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WATER METER MANUAL.

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THE

WATER METER:

Its Difficulties, Types and Applications.

A MANUAL

OF

REFERENCE AND FACT IN CONNECTION WITH THE SUPPLY OF WATER BY METER,

BY

WALTER G. KENT.

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INDEX.

CHAPTER I.

WATER METERS AS THEY SHOULD BE AND AS THEY ARE.

PAGE

Water-Meter Patents; Their number; extreme proportion of failures; cause of failure 1, 2

The Ideal Meter and its characteristics 2

Difficult conditions encountered by Water Meters:—

Hard waters.—Attack copper alloys 3

Growth on metal.—"Delta" metal 4

Soft waters.—Oxide.—Oxide resistants.—Silica enamel . 5

Other difficulties; great range of flow and of pressure . 6

High velocity flows without counter head . . . 6

Friction.—Water hammer.—Pulsating pressure . . 6, 7

Low pressures and small flows 7

Types of Water Meters 8

Distinguishing characteristics of the two great branches . 9

Positive Reciprocating-Piston Meters 9

Single cylinder reciprocating-piston meters . . . 9

Valves actuated by auxiliary means 10

Double-cylinder reciprocating-piston meters . . . 10

Mechanical (unpacked) pistons. 11

"Short-stroking." Cylinders of equal diameter. Cylinders of unequal diameter 11

General features of reciprocating-piston meters . . . 12

Positive Rotary-Piston Meters 13

General features of rotary-piston meters 14

The "Nutating" Meter 14

Diaphragm Meters 16

Low-pressure Meter.—As originally constructed.—Its modern outcome.—Another low-pressure meter . . 17, 18

General features of low-pressure meters 19

Inferential or velocity Meters 19

Fan 19

Turbine 20

General features of inferential meters 20

Effect of deterioration in positive and inferential meters compared 21

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PAGE

Waste-Water Meters.—A special waste-water meter . 22, 23
General features of waste-water meters 23

Water-Meter Registering Gear 25
The difficulty of making it easy working and durable . 25
The reducing gear of inferential meters;—of reciprocating-piston meters.—Various arrangements of reducing gear, and the materials most suitable for use therein . . 26

The Dials of Counters 27
Counter-reading and its difficulties 28

CHAPTER II.

WATER-METER PRACTICE AT HOME AND ABROAD.

Type of meter most in vogue varies greatly in different countries 29
Germany and Austria.—Belgium.—Holland.—France.—Russia.—Italy.—Portugal.—Spain.—England.—America 29, 30
Contrast between American and Austro-German practice . 30
Large consumption per head in the United States . . 30
Registration of small flows not much regarded by Americans at present 30
Registration of fine flows a necessity in England . . 31
Change in meter practice in England 31

CHAPTER III.

THE PURPOSES FOR WHICH METERS ARE REQUIRED, AND THE RESPECTIVE INSTRUMENTS WHICH ARE BEST ADAPTED THERETO.

The three chief divisions of purposes for which meters are employed 32
No one meter at present adequately meets ALL purposes, but there exists an efficient meter for each purpose . 32
The meter best adapted to each case should be chosen . 32
This course not always followed at present . . . 32
Selection of type of meter 33
Different points of view as to the comparative advantage of various types 33
Salient points of certain types of meters 35

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PAGE

The Classification of municipal purposes; of trade purposes; of domestic purposes 35, 36

Municipal purposes 36
Trunk mains 36
The meter most suitable for use on trunk mains . . 37
Detection of waste by the waste-water meter.—Economy effected thereby.—Results attained by use of waste-water meters 37
Road watering. The meter best suited thereto 39
Urinals ,, ,, ,, 39
Public baths ,, ,, ,, 40
Swimming baths only ,, ,, ,, 40
Public buildings, &c. ,, ,, ,, 40
Fire hydrants on bye-passes 41
Drinking fountains, water troughs, etc. The meter best suited thereto 41
Public gardens, etc. The meter best suited thereto 42
Ornamental fountains ,, ,, ,, 42
Flushing drains ,, ,, ,, 42

Trade purposes in general necessitate use of large quantities of water. The meter best suited thereto . . . 43
Small quantities taken at high velocities and used immediately, *e.g.*, Ship-supply. The meter best suited thereto 43
Small flows constantly running.—Possibly varied by larger flows. The meter best suited thereto . . . 44
Other conditions of supply for trade purposes. The meter best suited thereto 44
Supply of feed water to boilers direct by utilising effective head. The meter best suited thereto . . . 45

Various conditions of "mixed" supply 46
Mixed supply should be entirely by meter . . . 46

Domestic purposes:—
Three conditions of supply; constant supply with cisterns; constant supply without cisterns; intermittent supply 47
Advantages of cisterns.—Disadvantages of cisterns.—Cleansing of cisterns. 47, 48
Constant supply with cisterns.—Rate of flow at various times of the day.—Experiment showing average consumption per hour 48, 49
The meter best suited to measure constant supply into cisterns 51
Importance of registering the finest flows . . . 52
Sanitary minimum 53
Constant supply without cisterns. The meter best suited thereto 53
Intermittent supply. The meter best suited thereto. . 54

Summary of purposes and most suitable types of Meter 54

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CHAPTER IV.

THE PRICES AND THE VALUES OF WATER-METERS.

PAGE

The true measure of price gauged by three considerations . 56

The Meter must be suited to the work 56

Delivering capacity, and not nominal size, criterion of first cost 57

Insufficient data as to delivering capacity given by makers 58

Tests made to supply above deficiency.—Tabulated results of tests 58

Comparative price-value of positive and inferential meters 59

Suitability for purpose paramount to price-value . . 60

Positive meters have greater delivering capacity than inferential meters 60

Cost of Maintenance 61

Importance of reducing it to the lowest possible.—Variation of cost of maintenance 61, 62

Summary of the measure of price 63

CHAPTER V.

THE DELIVERING CAPACITY OF METERS.

A method of determining the size of instrument required . 64

Table I.—Free delivery of the Kent meter 65

Absorption of head by pipe-friction 66

Bends and elbows 66

Table II.—Loss of head through friction in pipes of various diameters 67

Variations from nominal size of pipes 67

Absorption of head by stop-cocks, stop-ferrules and screw-down valves 68

Table III.—Rates of flow corresponding to higher and lower heads 69

Example demonstrating use of tables and rules . . 70

CHAPTER VI.

HINTS AS TO SELECTING, FIXING, AND MAINTAINING WATER-METERS.

Selecting 72

Fixing 72

Maintaining 73

Reading 73

Periodical examination.—**Table** 73

Maintenance by contract 74

Testing. Testing apparatus 74

Digitized by Google

CHAPTER VII.

WATER-METER REGULATIONS, RENTS AND CHARGES.

PAGE

Regulations 77
Provision and fixing of meter 77
Accidents 77
Damage 77
Meter Rentals.—**Table** 77
Repairs 78
Notice as to discontinuing supply 78
Access 78
Removal of meter 78
Mal-registration 78
Testing at consumer's request 78
Connections of meter 78
Sliding scale of charges 79
Minimum charges for water by meter for trade purposes . 79
Suggested minimum charges for water by meter.—**Table** . 80
Table of Prices charged per 1000 gallons at various towns for water by meter for **Trade Purposes** 81
Waterworks and corresponding **charges** at each for water supplied for **Domestic Purposes** 82
Meter-readers 83

CHAPTER VIII.

SHOULD THE WATER-METER BE OWNED BY THE SUPPLIER OR BY THE CONSUMER?

Meters should be owned by supplier. 84
Meters form part of plant of waterworks 84
Consumer not prejudiced by this 84
Meter is supplier's ledger. 85
Meters out of repair always under-register. . . . 85
If consumer owns meter constant disputes involved . . 86
Where tried found unprofitable 86
Advantages of ownership by supplier 86
Meter-freaks 87

CHAPTER IX.

THE ECONOMICS OF WATER SUPPLY CONSIDERED IN RELATION TO THE METHOD OF PAYMENT.

Water Meters *versus* **Water Rates** 89
Water-supply of London and other towns becoming insufficient 89
Economical means of meeting the difficulty 89

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PAGE
Prevention of waste 89
Payment by quantity only efficient method . . . 90
Main principle 90
Payment should be for value received, *i.e.*, by quantity . 91
The advantages of meter-supply have been proved practically 91
Evils of rating-system—Arbitrary; unjust; wasteful 91, 92
Example of waste 92
Much of the consumption practically unpaid for . . 92
On the other hand, many consumers obtain a very poor return for their money 93
Example of overpayment. 93
In England, the consumer; in America, the supplier, demands meter system 94
Cause and effect of metering in America 95
Possible causes of difference of opinion between American and English engineers 95
Advantages to the consumer of meter supply . . . 96
Advantages to the supplier 96
Water-waste in London necessitating additional supplies . 97
The Liverpool water-supply 98
Estimate of water-waste in America 99
Meters superseding rates in Continental capitals . . 99
The use of meters by the London Hydraulic Power Company 99
Estimated cost of bringing new supply to London . . 100
Adoption of meter-supply advisable instead . . . 100
Probable effect and saving if this were done . . . 100
Effect on sanitation 100
The poor 100
Sanitary minimum 101
In London and other large towns in England adoption of sliding scale for the poorest classes advocated . . 102
Reason for reducing price to poor 102
Sliding-scale benefits rich as well as poor 102
In foreign towns no sliding scale.—Reason of this . . 102
Cost of measuring machine 103
Meter-rent 103
Sliding-scale should be extended to meter-rent, and one payment should cover both cost of water and of meter 103
Practical illustration of sliding-scale 104
Table giving comparison of systems 105
Cost of metering present supplies 107
Length of time before new supply available . . . 108
Meters at once provide further available supplies . . 108
Cost of fresh supplies 109
Comparison of respective costs 110
Need for economising all supplies in view of great growth of population 110
The town of Flushing, U.S.A., under rating system; under meter system 111
Results of metering at Flushing, U.S.A. 112

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PAGE
Table showing economy effected through the adoption of the meter system at the Flushing waterworks, U.S.A. 113
Hoboken, U.S.A. 113
Consumption under rating system 114
Saving effected by metering 114
Tables.—Comparison of receipts under rating and under meter systems at Hoboken, U.S.A 115
Results of metering at Hoboken, U.S.A. 117
Town of Atlanta, U.S.A.—Benefits derived by substitution of metering in lieu of rating system 120
Summary 120

Illustration 60A
Sketch, showing arrangements used in making the tests given on page 60.

Illustration 76A
Sketch, showing water meter testing room fittings, suitable for waterworks' use.

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INTRODUCTION.

THE object of these few pages is to furnish, for the use of water engineers and others, a means of ready reference to the theory and practice of "metering." In endeavouring to attain this end, it has been the aim of the writer—not, to attempt to advance any startling hypotheses, but—to collate, comment on, and compare within a brief compass the ascertained facts of this important, though veritably hydra-headed, subject.

In order to achieve this object, it is proposed in the first place to consider what is required of a meter that it may efficiently discharge all its functions, then to examine the various types of meter now obtainable, and to determine how far each one goes towards meeting those requirements.

The next step will be to discuss the conditions incidental to the divers purposes for which these instruments are used, and lastly to suggest as impartially as possible the particular types of meter which best fulfil them.

It is not intended to give any very technical formulæ, or diagrams of loss of head, accuracy, etc., as such laboratory productions are of little worth as regards the end in view, whereas a short review of the broad lines of actual fact,

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eliminated by experience, will, it is hoped, prove of real service. The economics of supply by meter *versus* supply by rate will be dealt with, chiefly by the aid of pertinent statistics.

It is particularly hoped that this little book may prove of service to those who, without previous deliberate study of the art of metering, may happen to be placed in charge of waterworks or water-distribution, and who may have to select meters for certain of the varied purposes to which they are applied.

The author acknowledges with no little pleasure and gratitude the valuable and ready help extended to him by many water engineers, of both London and the provinces, in supplying various facts and data used herein. As regards the rest, he has striven earnestly to present accurate facts, deductions and conclusions; still, the following pages contain matter that is of necessity controversial, and that does not claim to be more than a personal expression of the opinions of the author—a meter manufacturer. Whether his conclusions are well founded the reader will judge.

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THE WATER METER:

Its Difficulties, Types and Applications.

CHAPTER I.

WATER METERS AS THEY SHOULD BE AND AS THEY ARE.

THE Ideal Meter has been said to be the *ignis fatuus* of Waterworks' Engineers.

Water-meter Patents;

The records of the English Patent Office offer convincing evidence that this is by no means an idle assertion, for if all the water-meter patents they contain be counted, beginning with that of Crossley, taken out in the year 1825, and ending with the last in December, 1890, the very respectable total of 989 is arrived at.* And this for England alone. No doubt a great many of these have had their birth in other countries; yet many have been invented abroad and not patented here, and, in fact, the total for all countries reaches a much higher figure. One would surely conclude that the colossal expenditure of brain-power and money implied by a thousand patents must, when applied to the production of one description of apparatus, have achieved complete success again and again. But if we put the number of patents taken out against the number now surviving as commercial successes,

Their number;

Extreme proportion of failures;

* The number of patents taken out in England for the—

10 years ending 31st December,			1830,	was	3
,,	,,	,,	1840	,,	6
,,	,,	,,	1850	,,	26
,,	,,	,,	1860	,,	107
,,	,,	,,	1870	,,	202
,,	,,	,,	1880	,,	256
,,	,,	,,	1890	,,	389

For the one year ending 31st December, 1891, the number was 14.

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the proportion affords startling proof of the fallacy of this conclusion, and also of the desirability and extreme difficulty of the object sought. Even among these few survivors, which may almost be counted on the fingers of one's hands, there is still no one instrument that combines in itself *all* the desiderata of the ideal water-meter.

Cause of failure.

Yet very many of these actual failures are, theoretically, nearly perfect, and the cause of their want of success is not readily discovered even by experts on the subject, while those who have not studied it would probably be ready to assert that such well-designed apparatus *must* work satisfactorily. Apparently there is no more difficulty in the mechanical problem of producing an efficient water-meter than in that of creating an efficient gas-meter. But the difficulty is infinitely greater. Briefly, it lies in the fact that the latter works under nearly constant conditions, while the former has to contend with almost infinite variety and combinations of conditions. Herein lies the barrier to success in most instances. These conditions will be set forth and examined on a subsequent page.

In order to duly consider the merits and demerits of the water-meters at present on the market, and which have "come to stay," it will be convenient first to enumerate the requirements that the Perfect Meter should satisfy.

THE IDEAL METER

The ideal meter and its characteristics.

1. Should accurately measure all water passing at full flows.

2. Should accurately measure all water passing at fine flows.

3. Should work at a very slight pressure (effective head).

4. Should work at high speed (full flows at high pressure) without shock or water-hammer.

5. Should not reduce the flow.

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6. Should be quiet in action.

7. Should not be liable to "stick up," or stop.

8. Should, under ordinary conditions of water, flow, and pressure, do its work accurately for a period of three years without needing repair.

9. Should, with slight repairs (say not exceeding 2 per cent. per annum on its first cost), have a life-time of 25 years.

10. Should be constructed of such material as to resist the action of the varied salts and combinations of salts present in nearly all waters.

11. Should be moderate in first cost.

12. Should be small in bulk and handy to fix.

13. Should, when out of order, give some outward indication thereof.

14. Should have a register easily read.

15. Should be incapable of passing water backwards.

Despite the many efforts—extending in all over more than half a century—to produce this ideal instrument, there is not one of the hundreds invented that embraces *all* the foregoing attributes.

Difficult conditions encountered by water-meters.

Before examining the different types of meters in use, it may be well to briefly consider some of the conditions which militate more or less against one and all. The great difficulty—one but too familiar to all waterworks' engineers—is the varying quality of water at different works. Waters may be roughly grouped into Hard and Soft Waters. Hard Waters, containing a variety of carbonates, nitrates, and chlorides, act in a very remarkable manner upon most copper alloys. The most striking instances of this that the writer has seen are as follows :—

Hard waters

Attack copper alloys ;

A cylinder made of phosphor-bronze and forming part of a meter was found after four months' use at a waterworks in the North of England to be eaten into and pitted to

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the depth of $\frac{3}{32}$-inch. At another works a piece of perforated copper 20 B.W.G. and a brass casting about $2\frac{1}{2}$ inches in diameter and $\frac{3}{32}$" thick were so destroyed after being twelve months in the water, that they were crunched in the hand with no more resistance than brown paper. This destruction is probably brought about by galvanic action, all the elements necessary to a primary battery being present. It is difficult, indeed, to account for the rapid disintegration in any other way.

Growth on metal.

With other hard waters a growth on the metal presents itself. When this occurs, as it often does, in an inferential meter, in which, when new, the water-ways and passages are nearly always of less than the full area of the supply-pipe, the effect is to gravely increase the loss of head by wire-drawing the flow. It can be readily seen that in the arms of a turbine such a growth would unduly increase the calculated reaction, and upset the registration.

Many alloys have been tried in order to find one able to withstand such attacks. In two instances within the writer's knowledge the interior gun-metal fittings of inferential meters were silver-plated; but even this proved no more successful than tinning, which has also been tried and found wanting.

"Delta" metal.

"Delta" metal seems at present to be the only alloy, outside those of the precious metals—the price of which of course prevents their use—that is able to resist the attack of hard water, and engineers cannot do wrong in specifying it for any fittings for use therein.

Hard waters also attack the leather and indiarubber of which piston and gland-packings are made, sometimes causing them to harden, perish, and thus cease to be watertight, and sometimes cementing them, as it were, to the cylinder walls, causing the meter to "stick up."

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Soft water is less difficult to deal with; but no meter, the passages of which are made in iron, will continue to work efficiently for a long period in soft water unless all the exposed interior surfaces are thoroughly protected. Either the oxide will grow and break away in such quantities as to clog and interrupt the smaller working parts, or the passages become so choked with the oxide growth that the meter will only have a small fraction of its normal rate of flow.* Many methods have been employed, with varying measures of success, to cope with this oxide nuisance. The best known and most generally used are the Angus Smith and the Bower-Barff processes, while in some districts oxide paints have given fairly good results. But the cleanest and most enduring of all oxide resistants is silicate enamel. The art of applying this to untooled cast-iron surfaces has been much developed and perfected during the last few years, and there are now several firms doing the work so well that the enamel is quite unaffected by a far greater amount of expansion and contraction than can possibly occur to meters. When properly applied the enamel appears to be almost fused into the surface of the iron, so that oxidation cannot take place under it and cause it to flake off. In short, for this one evil it appears that an effectual remedy is at hand. At the same time, it is hardly necessary to accept the statement of a hyper-enthusiastic agent, who vigorously declared that, even if a meter were burst by frost, the enamel would still hold out! A coating of pure tin is a most excellent protective, and is also clean; but the art of applying it

Soft waters.

Oxide.

Oxide resistants.

Silica enamel.

Tin coating.

* Since writing the above a notable instance of this trouble has come under the author's notice. A meter of a well-known make was taken out after four years' use, because the consumer complained he could hardly get any water. It was found, on testing, that the meter took 3 hrs. 40 mins. to pass 100 gallons at a pressure of 70 lbs. per square inch. When the meter was new it would have accomplished the same work in about 7 minutes.

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well and cheaply to cast-iron surfaces needs development. Where meters are used for domestic purposes it is certainly of great sanitary importance that they be made of such material that, when left standing for hours without water passing, as is often the case, no dissolution of the metal occurs to contaminate the water.

Other difficulties: great range of flow and of pressure.

The next element of difficulty is the great range of pressure and of rate of flow to be encountered. There are two ways of working a meter very hard: one is to continually pass water through it full-bore, at a high effective pressure, without counter-head or back pressure; the other is to let water constantly dribble very slowly through at a very low head. This may seem a paradox, but it is a fact.

To be specific, an inch meter, for example, would be far less likely to get out of order in passing 1,000,000 gallons of water at rates of flow varying between 10 and 1000 gallons per hour, with a counter-head on the meter, than in passing a quarter of that quantity at a rate of 3000 gallons per hour, or even 10,000 gallons at a rate of 7 gallons or under per hour.

The reason is that when a meter is being worked at moderate speeds and with a counter-head, the co-efficient of friction of the moving parts remains low, and they are not strained, being held up to their work by the back pressure; but when running at a high velocity, without back pressure, the strain on the moving parts is out of all proportion to the work done. The co-efficient of friction of the working parts increases in all meters at a greater ratio than as the speed of the flow, the wear at 3000 gallons per hour for instance being more than three times the wear at 1000 gallons per hour.* In reciprocating-piston meters, and

High velocity flows without counter-head.

Friction.

* It should be noted that of the two factors of which water meter friction consists, one, viz., that due to the fluid friction of the water in its course through the ports and passages of a meter, has a practically

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in those rotary-piston meters which have not a constant discharge throughout their cycle of movement, there is another cause productive of undue strain and friction when working under such conditions. The resistance to the flow of water through a meter, which is generated by impact and fluid friction under normal conditions, increases approximately as through a pipe, that is, as the square of the rate of flow; but under the above conditions the increase is at a still greater ratio, until "water-hammer" is developed by the sudden check to the column of water at the end of each stroke, or at that point of the cycle where there is a diminution of flow owing to reduced port-area or increased friction. This check is communicated back to the water in the supply-pipe—and then comes the reaction. The pressure on the inlet side of the meter runs up far above the full statical pressure, and a pulsating pressure is generated, which is very trying to the constitution of any meter. This evil is greatly mitigated by back pressure, for then at the more favourable moments of the stroke or cycle the piston, having to move the column of water in its front, is prevented from racing, and is thus spared the consequent water-hammer.

Water-hammer.

Pulsating pressure.

Passing to the other extreme—low pressures and small flows—these combined conditions are more rare but not less troublesome. The effect of a very small quantity of water constantly passing is to collect all the grit and particles of oxide, etc., which are contained even in the

Low pressures and small flows.

constant ratio of increase, *i.e.* directly as the square of the speed—but the other, the friction *inter se* of the moving parts, varies with each type of meter. In hardly two instruments has it the same value; the moving parts of some meters are so arranged that an increased speed of flow tends to lift one working face from another and thus relieve the friction, while in other meters the D-valves occasion an increase of friction in direct proportion to the square of the speed of flow. This means that increase of friction is to increase of speed as four is to one.

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best of waters. This accumulation, which could not occur were the meter flushed out by a full flow, gets between the working faces, wears them unduly, and induces leakage. It also causes increased friction, which may get the upper hand of the low head, and bring the meter to a standstill. Stoppages of positive meters and non-registration by inferential meters occur more often under these circumstances than in any other way.

Speaking of the "best of waters" brings to mind a meter which, having been disconnected from a supply to an infirmary, was found to harbour in its dirt-box the largest collection of specimens of fresh (?) water life that could be contained in so small a space, beginning with a small eel, and ending with some little thing with a big name apparently not many stages down or up from the original protoplasm.

The chief extrinsic causes of difficulty met with in metering having been indicated, it remains to consider the different types of meters in use and the features peculiar to each.

The two great branches of the water-meter family are

the Positive—and—the Inferential,

which may be respectively subdivided into the following classes :—

Types of water meters.

Positive.	Inferential.
Reciprocating-piston single cylinder meters.	Rotary fan meters.
Reciprocating-piston double cylinder meters.	Rotary turbine meters.
Rotary-piston meters.	Waste-water meters.
Diaphragm meters.	* Low-pressure meters.
Low-pressure meters.	

* This meter is really hybrid, and should, perhaps, be described a posito-inferential.

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Nearly all of the above may be again divided into subclasses.

Distinguishing characteristics of the two great branches.

Positive meters of all classes actually *measure* the water passed in a vessel, or vessels, of known capacity, while inferential meters, as their name indicates, *infer* the quantity of water passed by the revolutions imparted to a fan or turbine by the water as it travels through the meter. The differentiating meter, which is inferential in its method of measurement, works in connection with a clock and shows the rate of flow at any moment. It is used as a waste-water meter.

Positive reciprocating piston meters.

Positive Reciprocating Piston Meters are constructed in the best practice so as to give the slowest piston speed possible. It is obvious that with a piston driven by a full port to the very end of its stroke the tendency to water-hammer will increase with the speed of the piston. [There are also other reasons that render a slow piston speed almost imperative, which will be dealt with on page 10.] The price paid to secure this object is increased bulk; in fact all meters of this class are large and heavy when compared with any other class. In illustration of this point: the 12-inch positive piston-meter of a certain make weighs seven tons, while there exists a 12-inch inferential meter weighing only four hundred-weights.

Single-cylinder reciprocating piston meters.

Reciprocating-piston meters may be subdivided into two classes, single-cylinder, and double-cylinder. The former is best represented by a well-known meter of high repute, and consists of a cylinder having its passages in connection with a four-way cock which is controlled by a tumbling-weight in connection with a rack worked by the piston-rod. By this means the inlet and outlet are alternately placed in connection with opposite ends of the cylinder at the completion of each stroke.

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The same effect has been attained in another meter of this class by the use of a spring actuating an ordinary D-valve. In another, the valve movement is governed by an ingenious arrangement, in which the atmospheric pressure is made to co-operate. The valve movement of all single-cylinder reciprocating-piston meters is actuated by auxiliary means.

Valves actuated by auxiliary means.

Where the valve is actuated by a tumbling-weight—particularly if it works in air, although the remark applies, in a less degree, to a meter which has a tumbling-weight working in water—a further reason for a slow speed is apparent, for not only do the concussion and noise of the weight falling become objectionable if the speed is too high, but the impetus causes the weight to throw over the centre and reverse the stroke earlier than it should. The evil of this short-stroking is, to some extent, obviated in the meter above referred to by the arrangement of the counter, which registers in accordance with the distance travelled by the piston. This meter requires lubricating from time to time, otherwise the friction of the four-way cock may at slow speed overcome the force of gravity acting on the weight, making it stick-up and stop the meter. Other meters of this class simply record the number of strokes made whether long or short, thereby causing the registration to be greater per quantity passed at a high speed than at a slow.

Double-cylinder reciprocating piston meters.

The number of two-cylinder meters is very great, inventors being probably attracted to this in preference to the one-cylinder class, from the fact that the whole cycle of movement is made under water-power, instead of weights, springs, etc., being employed as auxiliaries. The broad principle upon which all work is that each piston at the termination of, or during, its stroke, actuates the valve of the other. These valves are generally D-valves, but

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in a considerable number of meters the valves are formed in and by the pistons themselves. As this necessitates their being mechanical and not leather or rubber-packed pistons, it will be readily seen that leakage or slip is inevitable when fine flows are passing; whereas, with the separate valves and packed pistons registration of the very finest flows, even to drops, is obtained so long as the meter remains in good condition. The two cylinders are not always of the same diameter, in which case the small or auxiliary piston merely acts as turncock or valve-changer to the larger one.

Mechanical (unpacked) pistons.

Where the cylinders are of equal diameter there is a tendency to "short-stroke" and over-register when passing small flows—the reverse of the one-cylinder type, be it noted. Meters with cylinders of equal diameter generally have small rubber buffers to take the thrust of the pistons at the end of the stroke, which when small flows are passing—and consequently a smaller *effective* pressure acting on the piston—are less compressed than at a high speed and effective piston pressure, therefore the stroke is shorter and less water is actually displaced, although the same amount is registered, the counter being a multiple of number. In the case of the combined small and large pistons, the conditions that produce short-stroking are full flows and high effective head. The smaller piston requiring a greater pressure to operate it does not move (although its valves are opened) at slow flows and small effective pressure until the larger piston has completed its stroke, when the whole force of the flow is thrown on to the smaller piston, and it has to go; while at the higher speeds there is enough effective pressure to operate the smaller piston immediately its valves are reversed, which is effected by the larger piston during the last portion of its stroke. This prompt action of the smaller piston reverses

"Short-stroking."

Cylinders of equal diameter.

Cylinders of unequal diameter.

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the valves of the larger piston a little before the latter has finished its full stroke, hence there is less water displaced.

General features of reciprocating-piston meters.

Reciprocating-piston meters with packed pistons may claim to be good and reliable measurers of both full and fine flows, but it is in the registration of the latter that they surpass meters of all other classes (excepting the low-pressure meter), and this, for certain purposes, is an attribute of the highest value.

Considerable pressure is required to work some meters of this class owing to the friction of piston and gland packing and of the valves. They are high priced and expensive to fix on account of their bulk. Most are expensive to maintain in hard waters, which destroy the piston packing and cause them to stick-up and completely shut off the supply. The majority of water-engineers consider the annoyance, and even danger, thus caused to the consumer a far graver evil than that resulting from the loss of registration by a meter which still allows water to pass, even though it has ceased to measure it. In the latter case there is not much loss to the supplier, as it is the custom under such circumstances to assess the consumption at the average for the corresponding quarter or month. It is, perhaps, preferable when a meter fails in this way, that the flow be compromised but not stopped. The consumer is then likely to call attention to the fact. "Sticking-up" is particularly likely to occur if a meter be left standing for a few days; when the pistons may become set fast to the cylinder walls.*

* At two Companies' works, not eight miles apart, but one having soft water and the other hard, the same piston-meter has been used to a considerable extent; in the first instance with very good results, and in the second, with such constant trouble from meters stopping owing to the action of the water on them that they are being discarded as useless and hopeless.

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When piston-meters get seriously out of order, but without shutting off the supply, they generally cease registering entirely, which is distinctly a good point, since they do not pretend to be working correctly when they are really only measuring a fraction of the water passed.

Excepting some of those with the valves in the mechanical pistons (and these will not register fine flows) they cause concussion when working at high speeds.

Positive rotary-piston meters.

Positive Rotary Piston Meters all present the distinctive feature that their pistons or displacers move continuously forward, instead of with the reciprocating action of the piston-meters above referred to. They are so contrived that the only moving part in the measuring-chamber is the displacer or piston, which in its progress governs the opening and closing of the inlet and outlet ports. There are so many varieties of this class, several of which have been commercially successful, that beyond thus indicating the broad and distinctive lines upon which all are constructed it is impossible to describe their individual action without trespassing too much upon the reader's patience.

The result of this continuous forward movement is that a high piston speed can be attained without objectionable concussion, thus enabling meters of this class to be made comparatively small in bulk. The pistons are not packed, but, owing to the freedom with which they move, the difference of pressure between the inlet and outlet side of the working parts is so slight that they are practically *water-packed*, an infinitesimally thin film of water lying between the piston and the chamber in which it moves. The best of them may be described as "swimming frictionless," to which desirable attribute is due the capacity for passing more water than meters of any other class with much less wear and tear. Consequently their cost

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of maintenance is slight, especially when they are so made that the whole of the working parts can be readily removed without disturbing the fixing of the main body, or case, and its service connections.

General features of rotary-piston meters.

They are moderate in price if compared with other Positive Meters of the same nominal size, and cheap if measured by the quantity they can pass per hour. They are reliable, and will continue to register with their initial accuracy all flows but the very smallest, until very seriously out of order, when they will, as a rule, stop registering altogether, and will also call immediate attention to the fact by reducing the flow to a fraction of its proper volume. This feature is preferred by many engineers to entirely stopping the consumer's supply.

They are—no matter what the conditions of pressure—accurate measurers of all flows, except the very finest, when they are not so good as the reciprocating-piston instruments.*

But for this, Rotary Piston meters would come very near to the much sought-for "perfect" meter. As it is, some of them will give very good results on very small flows. Many thousands of meters of one particular make have come under the writer's notice, all of which tested well at five gallons per hour; but even this, though amply meeting the requirements of most, is not low enough for some purposes.

One instrument of the Rotary Piston class, while retaining the special feature of continuous movement, diverges so much in construction from its fellows that a short description may be of interest.

The "Nutating" Meter.

It is termed a "Nutating Meter," and the displacer (and

* This is particularly true of some meters of American manufacture, in which the fine-flow capabilities have not been developed to the extent possible and elsewhere deemed necessary.

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valve) takes the form of an oscillating disc, which vibrates, or "wobbles," in a constantly changing but circular direction within a chamber with spherical walls. The top and bottom of the chamber are formed by two cone frustra. The disc is carried on a ball which it encircles; the ball being supported, as by sockets top and bottom, between the two truncated cones. An arm attached to the ball at right angles to the plane of the disc passes up through the top cone, and is held at the proper angle of inclination by the lever which drives the counter gear, so that always some one diametrical line of the disc will be in contact with the top cone with one-half of its diameter, and with the opposite side of the bottom cone with the other half.

The disc does not rotate but only vibrates, or "nods," in a circular direction. At one point there is a radial slot in the disc through which a vertical partition passes from top to bottom of the chamber separating the inlet from the outlet.

This meter shares most of the properties of its class fellows, but it is not likely to maintain its initial accuracy so long, because any wear at the point of contact of the arm which gives the disc its angle of inclination, with the lever on which it abuts, or any wear of the spindle carrying the lever, permits the disc to break its contact with the cones, thus allowing water to pass direct from inlet to outlet. Since these points form the fulcrum of the movement and the action is very rapid, friction enough must be generated to cause unduly rapid wear. This form of meter has been also made in America for the last two or three years, and alterations have been introduced with a view to mitigate the above evil. These efforts have, strangely enough, taken diametrically opposite directions. One firm has directed its attention to a contrivance for taking up any wear, so that the disc must

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always retain its proper angle of inclination. Another has boldly discarded the inclining arm and lever, and relies solely upon the water pressure to maintain the contact between the disc and the top and bottom of the chamber. It is even claimed as an advantage that the disc of a nutating meter made on this principle can lift from its proper position and allow any grit or other foreign bodies to be blown through the meter by the passing water. This is probably true, but it must not be forgotten that when once the disc has broken contact with the top and bottom of the chamber it is practically balanced, as the water then has an unimpeded passage both above and below the disc from inlet to outlet. Slight friction, caused by any fine grit, or even by the impalpable deposit left by most waters, acting between the periphery of the disc and the walls of the chamber, might suffice to retain the disc in mid-stream. Any quantity of water may then pass unregistered. There may be advantages in this method: there are grave risks.

Diaphragm Meters.

Diaphragm Meters may be described as well-meant attempts to avoid the difficulties caused by the friction, wear, and sticking-up of the pistons of the reciprocating type, but the result, so far, has been to get "out of the frying-pan into the fire." The general arrangement of this type is similar to that of reciprocating-piston meters. The valves in single-diaphragm meters are actuated by some means, such as weights or springs, in addition to the water pressure: where there are two diaphragms, one controls the valves of the other.

Theoretically the diaphragm is all that can be desired, as both piston-friction and leakage are absolutely eliminated; but, unfortunately, use has demonstrated that it is impossible to produce a diaphragm made of

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such material that will not harden and crack, or that will not split with the constant bending. This tendency has been obviated as far as possible, in at least one meter, by forming the lower half of the displacing chamber with walls of a convex curve and the upper half with walls of a concave curve; but even this is not effectual. The diaphragms have also suffered from the small stones and grit which find their way into all water-fittings. Here they have perforated the soft material of which the diaphragms are made.

Low-pressure Meter;

The Low Pressure Meter has little likeness to any other members of the great meter family, whether judged by appearances or by characteristics. It would be better described as a No Pressure Meter, as it works in free communication with the air without any water pressure whatever, the actuating force being gravity.

As originally constructed.

The best known meter of this type is the outcome of that originally invented by Samuel Crossley in 1825. It consists of a drum, divided into segmental compartments, revolving within an outer case, which has an outlet connected a little below the centre line of the revolving drum. The inlet flows into a small chamber, wherein the water is kept at a constant level by means of a ball-cock. From this chamber a pipe conveys the overflow into the revolving drum through a small concentric opening in one side. The compartments are so placed in regard to this inlet pipe that one keeps filling until, by the gradual revolution of the drum caused by the increasing weight, the succeeding compartment begins to take the inflow, when the former slowly empties into the outer case; and so on, one after another.

Its modern outcome.

As now constructed a portion only of the water is measured, the remainder flowing straight through into

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the cistern or waste, the quantity being computed by that which is actually measured. This is effected by means of the small chamber—into which the water passes when first entering the meter—having a given number of apertures of equal sizes, so that if there were five apertures the water would be measured that passed through one only, and the counter so geared that this quantity would be multiplied by five in registration. It is questionable whether this meter should not be termed inferential rather than positive.*

Another low-pressure meter.

In another Low Pressure Meter, the water, the flow of which is controlled by a ball-valve, passes into a tilting tank having two compartments, and so balanced that when one is filled to a certain degree its weight causes it to upset, emptying its contents into a tank below, at the same time bringing the other compartment under the inflowing water, which in its turn tilts and empties, and so on.

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* Since writing the above, the author has seen one of these meters opened which had been about two years in use. It had been passing water containing some fibrous particles which had collected about these apertures. The registering aperture was reduced to about one-sixth of its original area, while the non-registering apertures presented nearly two-thirds of their proper areas. This would result in a loss of registration of about 75 %.

On the other hand, it might have happened that the non-registering apertures were choked, while the registering aperture remained clear, causing an over-registration of 400 %. It will be seen that, in this way alone, without considering the possible error due to the mechanism of the meter, there is a possible range of error of registration of 500 %, *i.e.*, from −100 % to + 400 %.

The chance of error from this cause is much increased on account of the meter being a "no pressure" instrument. Were the water-pressure available, it would scour and sweep away all or nearly all such disturbing elements, instead of letting them gently settle and cling to the sides of the apertures.

In justice to this meter, which, as a rule, performs its work very efficiently, it must be borne in mind that such a blocking of the apertures as is here described can only occur where the water carries with it an unusual proportion of foreign matter.

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General features of low-pressure meters.

These meters are very accurate, unless in the form first described some obstruction should happen to cover one of the apertures, when the registration may become wild; but on the whole they are reliable instruments for the class of duty, and not costly to maintain.

They are very bulky and expensive in proportion to the quantity of water they will pass, and they must be fixed at the highest point of the service, so that the supply can run from them into cisterns. Rising mains and cisterns are therefore an additional expense incidental to a meter of this kind. The 'pro's and con's' of the cistern question will be found on a subsequent page (47). It is often urged against the low-pressure meter that it makes the meter-reader's monthly or quarterly visits very objectionable, as he has to tramp up right through the house in order to get to the meter. The dishonest consumer—not quite such a *rara avis* as one would hope—has a tempting opportunity for tapping the rising main in front of the meter, and getting as much water as he chooses without payment. Low-pressure meters are considered by many engineers admissible only in cases where small quantities and no pressure are required.

Inferential or velocity meters.

No class of meter has been so widely used as the Inferential or Velocity meters, and possibly, because of their small first-cost, they are still being more largely manufactured than any other. They are made either in the fan or turbine form. In the former the flow is made to impinge on the blades of a fan working within an outer case, which, in the smaller sizes, is generally made of brass. The plane of the blades is either approximately parallel with the axis of the fan-spindle, in which case the water is admitted by lateral openings into the fan chamber, or the blades are set diagonally, and then the

Fan.

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water passes vertically from inlet to outlet. Efforts have been made in several inferential meters to minimise the wear of the foot-bearing of the fan-spindle. For instance, the blades of the fan have been set at such an angle, and the position of the inlet and outlet ports so arranged, that the force of the current tends to counteract the weight of the fan and its spindle.

Turbine.

Where the turbine is employed, it is pivotted vertically within the outer case of the meter, the water passing down into the centre and out tangentially from the turbine arms; the resistance to these water jets reacts on the turbine, causing it to rotate in a direction opposite to the flow. Blades or "dragboards" are attached to the bottom of the turbine to prevent it over-running. A provision of this kind is essential in all inferential meters, and is accomplished in different ways. One of these is a pocket or recess in the fan-chamber, which creates a back-flow or eddy. Were this not done a meter would continue registering after the flow had ceased, as the swirl of the water in the fan-chamber would be some time in stopping. The result in cases where taps were being frequently opened and shut would be to register a very much larger quantity than was actually passed. As it is, there is still room for further improvement in this respect. Several of the existing devices greatly mitigate, but none entirely obviate, the evil.

General features of inferential meters.

Meters of this type are compact, light, and low in price for nominal sizes, but not equally so when compared by capacity of rate per minute. Owing to the high speed at which they run, it is necessary to renew some of the parts rather frequently; but these renewals are less expensive, if more frequent, than those required by some other classes of meters. Inferential meters are, when in good repair and of careful manufacture, reliable in the measure-

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ment of all flows of high and medium speed, but are not good in the registration of small or fine flows. In this last particular nevertheless there is a great difference in the sensitiveness of meters of different manufacture. For instance, one German maker publishes in his catalogue that his ½-inch meter does not commence registration until the flow exceeds 35 gallons per hour, while an inferential meter of Austrian manufacture of the same nominal size will, when new, register a flow of 6 gallons per hour with tolerable accuracy. Both these meters are very largely used in their respective countries. English meters of this type give results similarly varying, though not to the same extent.

The most undesirable feature in an inferential meter is that the continuance of its initial accuracy, even on large flows, depends so greatly on the maintenance of the meter in *perfect* condition. In other words, the coefficient of the friction of the working parts should remain constant, which, with high speeds, and the grit and other foreign bodies more or less present in all waters, is practically impossible: more or less deterioration thus occurs, with the result that the meter begins to run slow and under-register. The evil effects resulting from this deterioration are far more serious in an inferential than in a positive meter. The following are the reasons:—In piston-meters increased friction only means an increased absorption of head in working, because water cannot pass without operating the apparatus; and even if the working parts are so worn that they are not absolutely water-tight, they yet offer so large an area of piston-surface to the effective head that, except on very fine flows, the proportion of the total surface under pressure in which slip or leakage can occur is such a minute fraction as to be almost immaterial. In inferential meters, on the other hand, increased friction

Effect of deterioration compared in inferential and positive meters.

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or even stoppage of the moving parts hardly affects the delivery, as the water-ways are not thereby obstructed to any appreciable extent.

It therefore constantly happens in practice that a serious percentage of the water passed is unregistered, although *to all appearance* the meter is doing its work as well as when first put in the ground.

It is a very difficult matter to detect this loss by comparing the registrations for similar periods, as not only does the consumption really vary in most instances, but the consumer is not likely to help in rectifying an error which tells in his favour. Detection is further hindered by the gradual way in which the loss begins and grows.

This failing is very marked on account of the big figures in meters of the larger sizes. It has been recently found at a waterworks, where some 3-inch and 4-inch inferential meters had been some years in use, that the registration was over 30 per cent. less than the actual consumption, although the meters when at work were always full bore. In one case alone 1,000,000 gallons a month were being lost to the company supplying the water. Had this error occurred suddenly, it would have been surely detected, but the gradual diminution prevented suspicion. Where inferential meters are used, it is a necessary precaution to take them out at regular periods for testing and examination—once a-year, if fair accuracy be desired, or oftener, should they have registered meanwhile more than a certain quantity (see page 73). In the great majority of cases this will prove to be a smaller expense than the loss by under-registration which would otherwise occur.

Waste-water meters.

There remains yet one other class of meter, but it has a distinct use of its own. This is the Waste-Water meter,

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which instrument differentiates the speed of the flow in mains, and consists of a valve which opens in proportion to the quantity passing at any moment. The movement of the valve is recorded on a diagram affixed to a cylinder, which by a clock-work arrangement is made to revolve once in the twenty-four hours. Parallel lines on the diagram correspond to certain rates of flow per hour, so that by following the line traced by the pencil in connection with the valve the rate of flow at any moment can be instantly ascertained.

The valve used in the original waste-water meter, which has since become widely known and used, consists of a disc working in a conical passage.

A valve of the ordinary reflux type is used in a recent meter of this class. This allows a straight and clear water-way—a distinct advantage in cases of large draught and small pressure. When fixed near a pumping station it should minimise the vibration of the recording pencil by checking the pulsation.

A special waste water meter.

Other meter-manufacturers produce a waste-water meter on rather different lines to the above—an ordinary inferential meter working in connection with a clock and tape. It possesses the feature—and advantage—of showing the exact total quantity passed without the necessity of averaging the rate, mentioned above. At the same time, it records equally well the flow at any moment.

This system could be applied to any meter with similarly good results.

General features of waste-water meters.

The bulk and cost of waste-water meters is of little moment because comparatively few are needed, and also because they are fixed in roadways where there is generally room and to spare.

They are accurate and reliable, though the correct reading or averaging of the diagrams they give is a matter of

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some little practice and judgment on account of the many alterations of rate of flow in a short space of time.

It is not necessary to work these meters excepting occasionally when diagrams are required with a view to search for waste or leakage in mains or fittings. To this end they are usually placed on a bye-pass.

The Venturi meter.

Experiments were made in the United States,* in 1887, with the Venturi meter, but the writer is not aware that the system has yet been put practically forward to any considerable extent.† This instrument is best suited for use as a waste-water meter, as it indicates the speed of flow at any moment. It would appear, however, that the recording mechanism must necessarily be more complicated than that of any of the above mentioned instruments.

The meter consists of a short conical reducing-piece let directly into the pipe-line, the reduced end having a diameter of about one-third of that of the main; to this is attached the "Venturi" mouth-piece, a long expanding cone, the small end matching and attached to the small end of the reducing cone, and the large end joining the main. When water passes through this arrangement it causes a strong sucking action, and consequently a great reduction of pressure in the "throat" of the apparatus. An annular air-chamber is formed round the outside of the throat; small holes drilled through the pipe connect the two. Pressure gauges are fixed to the main a little before the meter and to the air-chamber at the throat. The difference of pressure caused by the depression in the hydraulic gradient at the "Venturi" is registered by

* See paper read by Clemens Herschel, M. Am. Soc. C.E., at a meeting of the American Society of Civil Engineers, December 21st, 1887.

† In the American "Engineering News" of July 7th, 1892, there is an interesting account given of the subsequent progress made with this meter.

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manometers or other suitable gauges. The quantity passing can then be arrived at by calculating the discharge from the orifice or throat of known area at the pressure thus ascertained. The figures obtained from a long series of careful experiments demonstrate that reliable results may be obtained with a considerable range of velocity. At speeds below half-a-foot per second in the pipe-line, there is great difficulty in obtaining accurate readings from the gauges.

The "Venturi" tube appears to embody the vital principle on which work the many injectors and "jet pumps." It is further interesting from the fact that its sucking or inducting power appears to have been known long before the days (A.D. 1791) of the man by whose name it is now known: the Romans are believed to have cheated the water authority of Ancient Rome by attaching a Venturi tube to the stamped and calibred regulation orifice, which constituted every citizen's water-right.

Water-meter registering gear.

COUNTERS.—The registers or counters have not been described with each variety of meter, because they do not necessarily differ to a corresponding degree.

The difficulty of making it easy-working and durable.

It has been said by an eminent waterworks engineer that anyone can make a meter, but that no one can produce a really reliable counter. This perhaps was only intended to forcibly convey the fact that it is a far harder matter to obtain an easy-working and durable counter than is generally imagined. The experience of most waterworks engineers would probably corroborate this. A tabular digest of the repairs needed to meters of a good inferential make, which is annually prepared by the water department of one of the Continental capitals, shows that 52 per cent. of the total repairs are to the register; and this is in the maintenance of a large number of meters, so that the percentage should be representative of the truth.

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The reducing gear of inferential meters;

Inferential meters wear their counter-gear more rapidly than positive meters, on account, probably, of the greater reduction of speed necessary between actuator and register, although in many such meters the reducing gear works in some lubricant. Nevertheless the proportion of counter repairs is greater than seems justifiable in all classes of meters.

Of reciprocating-piston meters.

In packed-piston meters, in which the friction of the counter-spindle stuffing-box is of no moment, the reducing gear should be placed outside the main body of the meter, so that it works dry. A fruitful source of trouble would thus be avoided.

Various arrangements of reducing gear, and the most suitable material used therein.

Worm-gearing working in water.

The reducing gear in inferential and in rotary positive meters consists either of a train of spur-wheels, or of worms and worm-wheels, working either in water, or in some better lubricant, such as glycerine, vaseline, or oils containing no acid. If worm-gearing is used, working in water, vulcanite is used instead of brass or gun-metal, either in the wheels or worms. A reducing train of which the worms are vulcanite and the worm-wheels brass will, *cæteris paribus*, outlast similar gearing made entirely in brass, even if five times renewed. Worms and wheels both of vulcanite work well so long as the water is free from grit, but in dirty water they drag much more than the composite gear. It is better to make the worms of vulcanite than the wheels, as in the event of any undue strain occurring, the single tooth of the vulcanite wheel which is for the moment in gear might be unable to support it, while the strain thus thrown on to a vulcanite worm would be distributed throughout the length of its spiral. If a gear of this kind be working under conditions most favourable to friction—such as very gritty water, and journals and glands too much tightened—so long that appreciable wear occurs, it will be the hard brass and

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not the comparatively soft vulcanite that is most worn. The reason of this is that the vulcanite allows any hard and sharp particles that may be pressed firmly against it to become partly imbedded, so that it then forms a species of tool-holder and cuts away with the projecting edges of the partly imbedded particles the hard metal surfaces with which it comes in contact in working.

Spur-gearing.

If the gearing be spur-wheels and pinions, then brass for both is preferable, as there is little frictional contact to wear the metal, and were vulcanite used the teeth might break under sudden or increased strain.

Worm-gearing working in lubricant.

Worm-gearing working in a lubricant should be made entirely in metal, but parallel bearings of fair length are preferable to the small cones often used, as although these may work with less friction at first, they have so small a bearing surface that they soon become worn, and allow the wheels to jamb, if not to get out of gear. Reciprocating-piston meters generally impart a rotary motion to the first spindle by a pawl and ratchet-wheel working either within or without the meter, the speed being further reduced either by toothed-wheels or worms and worm-wheels working outside the meter (by "outside the meter" is meant outside that part to which the water has access).

The dials of counters.

The actual registration in the majority of meters is effected by a five or six-hand dial—very much like the ordinary gas-meter dial. In some there are two or three small hands for the higher denominators, while the units up to one thousand are marked by a large hand moving round the whole face of the register. In others the dial itself moves for the first thousand or hundred, the indication being given by a pointer attached to the wall of the counter box, at the same time a hand moving on the dial records the next higher denominator on an inner

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circle of figures, the still higher denominators being recorded by two small hands. Another method is to employ a Harding's counter, so that the registration is read straight off a line of figures.

Counter-reading.

So many varieties of registers are very puzzling to the inexperienced meter-reader, who, in addition, is often at a loss to know the value of a revolution of a hand round one of the small dials, which may, for example, be marked outside the circle "thousands," and inside with figures at regular spaces 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10. The question is, Are the revolutions of the hand "thousands" or "tens of thousands"? The latter is the correct answer, but not by any means that always given. On the other hand the dial may be marked "1000," in which case each complete revolution registers 1000 only.

Difficulties of counter-reading

In illustration of the trouble and disputes arising with consumers owing to the liability to mistakes in reading the dials of these diverse patterns, an engineer informed the writer that at a works of which he had charge, and at which a large number of meters of different kinds were in use, he had such constant trouble from this cause that he devised the plan of sending out his meter-readers armed with twelve different books, each book containing facsimiles of the dial or register of one particular meter. The reader then simply marked on the facsimiles the positions of the hands, at the same time giving a copy to the consumer. These books were then returned to the office to be interpreted. Did any dispute arise subsequently, which rarely occurred, it was easily and definitely settled.

Registers, as regards both reducing gear and dial work, are kept small in the effort to make meters as little cumbersome as possible, and to keep down their cost; but a clear and intelligible dial should be insisted upon by all purchasers.

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CHAPTER II.

WATER METER PRACTICE AT HOME AND ABROAD.

Type of meter most in vogue varies greatly in different countries.

The great international diversity of practice in the type of meter used is at once interesting and perplexing, the class of meter almost universally adopted in one country, and with but slight exceptions even in one continent, being unknown except by reputation, or as a museum specimen, in another.

Germany and Austria. Belgium.

In Germany and Austria the inferential meter is used to the almost entire exclusion of all others. Belgium strongly favours reciprocating-piston positive meters, while maintaining a fair number of the inferential.

Holland. France. Russia. Italy. Portugal. Spain.

Holland is in a transitory stage, the inferential being superseded by the positive. In Paris none but positive reciprocating meters are permissible, although the two classes share the trade in the rest of France. Russia and Italy use both types to a considerable extent, but hitherto have manufactured none. In Portugal and some parts of Spain low-pressure meters of the tilting order have been widely adopted, but for the past few years there has been a disposition to oust them in favour of their high-pressure rivals.

England.

England is the great battle-ground of the advocates of the various instruments, nearly all of which have been tried on a considerable scale at some time or other. The various types still contend for the favour of waterworks engineers, nevertheless positive meters, especially of the rotary-piston type, have gained much ground of late.

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America.

Meters are used more largely in America than in any other part of the world, and while there are a fair number of reciprocating-piston meters with unpacked pistons at work, the enormous majority are of the rotary piston type, and their ranks are being reinforced to the extent of about forty thousand new meters annually. There are also a few reciprocating meters with packed pistons in use here and there, but the inferential type is practically unknown. It will be seen that Austro-German and American practice offer the most strongly marked contrast, the reason probably being that in the former countries low first cost is an item of the highest importance. The *philosophic* Teuton contents himself with a fairly accurate instrument at a small price rather than strive after greater exactitude at a greater initial expense. Then the consumption *per capita* is very considerably less than in the United States, which, coupled with the comparatively high minimum charge often adopted, greatly relieves the strain on both the maximum and minimum capacities of the meter. Taking these points into consideration the inferential meters, which, especially the Austrian, are good of their kind, fairly well meet the requirements of the situation.

Contrast between American and Austro-German practice.

Large consumption per head in the United States.

Americans use a very large quantity of water per head per day, even 100 gallons being by no means rare. They therefore need an instrument of greater maximum capacity and of greater durability. First cost is a matter of no great moment, while the operation of a positive rotary-piston meter appeals more directly to their mechanical minds than that of the inferential.

Registration of small flows not much regarded by Americans at present.

Owing to the plentiful supplies at present available, and to the lavish way in which water is used in the States, there are but few advocates of the exact registration of the very lowest flows; hence the few positive

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packed-piston meters, and also the undeveloped minimum-flow registration-capacity of the rotary-piston meters at present in use. It is a question, however, with the rapidly increasing population, and consequently diminishing supply of water available per head, whether this point will not, in cases of domestic supply at all events, force its way to the front.

Registration of fine flows a necessity in England.

Most English engineers have been more exacting in their requirements than their Continental and American *confrères*. Animated by a desire to obtain more accurate registration of the water consumed, they have tried one after another all the systems available. Water waste can be ill afforded in a country so thickly populated, and only having the moderate average rainfall of 27 inches annually.

Change in meter practice in England.

At first the inferential meters, owing doubtless to their evident advantages of size and cost, were extensively adopted, and in some parts of the country they still predominate; but during the last few years a general reaction in favour of positive meters has pervaded the country, and both the reciprocating-piston and the rotary-piston meter have come widely into use. The rotary-piston type, although of comparatively recent introduction into England, has made more rapid progress in the time than any other. The use of low-pressure meters extends over a long period, but their application has been limited to special purposes and circumstances.

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CHAPTER III.

THE PURPOSES FOR WHICH METERS ARE REQUIRED, AND THE RESPECTIVE INSTRUMENTS WHICH ARE BEST ADAPTED THERETO.

The three chief divisions of Purposes for which meters are employed.

The purposes for which water-meters are employed may be grouped under three principal heads, viz.: (1) for Municipal or Parochial Service; (2) for Trade Supply; (3) for Domestic Supply. These, however, may each be sub-divided into several minor ones, in nearly all of which the conditions of work vary not a little.

No meter at present adequately meets all purposes.

As no meter has yet been produced which will adequately fulfil all these varying conditions, it would seem wise to select for each purpose the instrument best adapted to the requirements of the case; but several causes at present combine to prevent this course.

The meter best adapted to each case should be chosen.

The selection of the meter to be used falls either to the consulting or resident engineer of a waterworks. If he, perchance, has not had opportunity of studying practically the art of metering, he naturally selects the cheapest instrument, or that having the best reputation for the time being. Or, if it happens that he has been able to devote but limited time to the acquirement of experience in metering, it is conceivable that he is unduly influenced by favourable results given by a particular meter in some special case, and biassed against other meters which may have done badly under similar conditions; while it is quite possible that this has occurred through the one instrument being the particular one for the specific purpose,

This course not always followed at present.

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and the others unsuited. He then orders on the strength of his former experience, and, should the nature of the work differ, probably finds the results reversed. Again, the desire—and excellent it is in most other cases—for a uniform pattern of fittings induces engineers to try to use one pattern of meter all through their works. This aspiration, however, should be stifled at its birth, as the trouble caused by meters being put to the wrong work results in so much vexation of spirit, that nine times out of ten the engineer is induced to try many other kinds of meters. Even then these may not get put in the right places until continued unsatisfactory results cause a deeper study of the difficulties of metering and of their remedies or preventions.

Selection of type of meter.

Engineers who still prefer to employ one kind of meter, while recognising the fact that all purposes cannot be equally well served thereby, have to select that combination of good points and bad which appears to them to offer the best average under the particular circumstances—of pressure, nature of water, and purposes of the work to be supplied. It is but human that, given the same conditions, there is no unanimity as to the most desirable instrument, hence is more strongly accentuated that disagreeably evident truth to manufacturers, that no one instrument will satisfy the ideas and requirements of all engineers. One may select the Inferential because of its low first cost, accuracy on full flows, and small bulk, holding that fine flows form so small a portion of the total flow that their non-registration is immaterial. Another will say that fine flows are more important than others because constantly running through leakage, &c., and that unless registered they coach the dishonest consumer to steal to the utmost possible drop; therefore, he must have a Reciprocating Piston meter, and if there

Different points of view as to comparative advantage of various types.

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is water-hammer at occasional full flows—well, no matter; the price is high, but it is worth it. A third will, after halting between the opinions of the other two, conclude that the Positive Rotary meter is the one for him, embodying many of the virtues of inferential and reciprocating-piston meters, with a minimum of their failings; and so on.

Who is to say which of the three is wisest? Good arguments can be adduced in support of each, but proof is impossible in every case where, as is usual, there is a variety of purposes to be served by the one meter.

It is here contended, and will, it is submitted, be demonstrated in the following pages, that all three of the above supposititious but representative gentlemen are wrong, and that until a meter more nearly approaching the ideal is available no one type can properly be put to all existing uses. Before considering the conditions appertaining to the various uses it will be well to briefly recapitulate the salient points of the different types of meters.

These descriptions necessarily apply to the class generally, without reference to any exceptional feature which may be presented by particular instruments.

In doing this it will be well to leave out of consideration the low-pressure meters, as the characteristic to which they owe their name has precluded their use for many general purposes, and restricted it for others. Nevertheless, in some special cases they are very desirable.

Although many diaphragm meters have been introduced experimentally, there are none yet available for active service, so they also must be allowed to fall out of the ranks.

The waste-water meter is neither intended for nor adapted to the use of any but the one purpose, which is referred to on page 37; it would therefore be both useless and unfair to consider its applicability to other functions.

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There are then remaining for selection—

Salient points of certain types of meters.

THE RECIPROCATING PISTON METERS with *packed pistons*, which possess the special feature of measuring small flows accurately, but which should not be constantly run at very high speeds. They are bulky and rather high in price. Some are not satisfactory at very low effective heads.

English Engineers do not affect RECIPROCATING PISTON METERS with *unpacked pistons*. These have no special feature. They are not so efficient as the last class, and quickly deteriorate. They are not suitable for fine flow work, but some of them may be run at high speeds without objectionable concussion.

THE ROTARY PISTON METERS, which cover a wider range of flows than any other class. They may be run at high or slow speeds, with high or low pressures, giving satisfactory results at all, but they are not suited for the constant measurement of the very slowest flows only.

There is at present a considerable difference in fine-flow registration and in durability between English and American rotary-piston meters.

Then there are the two INFERENTIAL or VELOCITY METERS, the *turbine* and the *fan*, both of which are good on full flows, but indifferent instruments for fine-flow registration, which, coupled with their not maintaining their initial accuracy when doing heavy duty, indicates their employment on supplies of comparatively small quantities taken at medium or fairly quick speeds. They are small and compact, and of low first cost.

The classification of Municipal purposes;

Water-meters for *parochial or municipal* work are used in the following services: district or sub-town supply; road watering; the supply to urinals, public baths, buildings, institutions, parks and fountains.

Of Trade purposes;

For *trade purposes* the work is infinitely varied, small

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quantities always passing in some cases, large quantities in others; or perhaps the whole supply may be taken in a short space of time at a very high rate of flow; then again there are supplies in which the flows are irregular, both as to rate of flow and as to time.

Of Domestic purposes.

Domestic supply may be divided into three classes; intermittent with cisterns; constant with cisterns; and constant without cisterns.

These many uses for water-meters embrace every variety conceivable of condition of flow and of pressure; it will be well, therefore, to consider them *seriatim*.

MUNICIPAL SERVICE.

Trunk Mains.

Meters are used on Trunk Mains either to determine the total quantity passed into a district or town within the boundaries of the supplier's monopoly, or to measure the water supplied to some other town or rural authority not having a supply of its own. In either case water is almost constantly passing at medium and slow speeds, never at very high velocities in proportion to the size of main and of meter, and very rarely, if at all, at very slow flows. For example, repeated experiments at different waterworks have given the data for the following table:—

Average maximum and minimum speeds of flows passing at any moment, night or day, in the trunk and district mains, of certain English Towns, shown in gallons per hour.

Diameter of Main.	3″	4″	6″
Maximum ...	4000	6500	12,000
Minimum ...	175	250	450

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The Meter most suitable for use on Trunk Mains.

Still, as the running is continuous, the work done by the end of a year is represented by a high figure. The rotary-piston meter is best for all such purposes because of its greater durability, continuance of initial accuracy, and free delivery. The inferential is unsuitable in that it lacks these qualities, and that it "choke-bores" the main; the reciprocating-piston either occasions too great a loss of head, or is very cumbersome and noisy for a roadway, under which meters for this purpose have often to be fixed. In some instances they require frequent attention.

Detection of Waste by the Waste-Water Meter.

In connection with trunk and district mains the waste-water meter is invaluable in detecting leakage, and should be included in the plant of every waterworks where the authorities are not content to let a heavy percentage of the water pumped run to waste.

Economy effected thereby.

It is indeed a matter of some surprise that a system which effects so great an economy at so small a cost has not been more widely adopted, and it may not be out of place to give the results attained in some few of the towns where the waste-water meter has been used:—

Results attained by use of Waste-Water meters.

Name of Town or Waterworks.	Consumption per head in gallons before the introduction of the waste-water meter.	Consumption per head in gallons after the introduction of the waste-water meter.
Abergavenny ...	42	17·2
Bath	36	12
Birkenhead ...	24·01	17·7
Bolton	32·52	14·8
Boston, U.S.A. ...	95 U.S. galls.	50 U.S. galls.
Bradford	22·47	14·35
Carlisle	42·5	24
Chelsea Water Co.	40	16
Chester	31	13·5

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Name of Town or Waterworks.	Consumption per head in gallons before the introduction of the waste-water meter.	Consumption per head in gallons after the introduction of the waste-water meter.*
Clevedon	40	20
Exeter	60	25
East London Water Co. ...	26·53	16·14
Gloucester ...	32	17
Glasgow	51·3	40·8
Hereford	53	24
Hertford	38·5 (intermittent)	17·5 (constant)
Lambeth Water Co.	35 (intermittent)	24·8 (constant)
Lancaster	51·37	34·36
Leamington ...	23	16
Liverpool ...	33·5 (constant) 24·47 (intermittent, exclusive of trade)	17 (constant exclusive of trade)
New River Water Company ...	26·4	14·05
Portsmouth ...	35	18·3
Southampton ...	60	39·5
Southwark & Vauxhall Water Co.	38·09 (intermittent)	22·23 (constant)
Stamford	24	18
Salisbury	50	31·66
Kent Waterworks Company ...	159 per house	98 per house

*In some of the above cases the figures refer to certain districts only, as the whole of the town or works was not metered.

Inspection with the aid of a waste-water meter is discriminate search after a proved leakage, instead of the usual indiscriminate and aimless hunt after waste that is vaguely believed to exist—somewhere.

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But although these instruments are altogether efficient for the detection of waste, it must be borne in mind that they are neither intended for nor adapted to the actual measurement of the total quantity passing through a main.

Road Watering.

For Road Watering purposes the most suitable meter is the inferential. Although the water is all passed at full bore, yet the total quantity taken during a season is small, as the meters do absolutely nothing between each time of filling the water-carts. Therefore the initial accuracy is not likely to become impaired, and as the general practice is to remove these meters in the winter, when they are not required, to avoid the risk of damage by frost, there is ample opportunity of re-testing and examining them at a very small extra cost, before they are replaced for the next season's work. The restriction to the rate of flow caused by instruments of this type is partly counterbalanced in the case in point by the absence of counter-pressure, which condition is adverse to piston-meters of either type.

The meter most suitable for road watering.

The small bulk of inferential meters enables them to be conveniently placed under the "side-walks," close to the base of the stand-posts they supply. As it is usual to select meters for this purpose by their nominal size rather than by their rate of delivery, they also show an advantage in first cost.

Urinals.

The supply to Urinals is the exact reverse of the one just considered. Instead of a few intermittent flows at high speeds, there is a constant flow throughout the whole twenty-four hours at slow or very slow speeds, according to the size of the urinal; this rate may perhaps be varied for a few minutes once a day, when the place is washed down and cleaned out. Except in the large urinals, where rotary-piston meters may be also used, recipro-

Appropriate Meter.

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cating meters with packed-pistons should be used in preference to all other types. If the pressure be low, the single-cylinder meter is preferable, as it works with a smaller head than any of the two-cylinder class, owing to the nature of the piston packing.

Public Baths.

Public Baths' supply involves a heavy strain on the meter, as the consumption is very large in proportion to the size of the supply pipe, and consequently of the meter also. The work is spread over a good many hours, but is very irregular. Some departments of such an establishment require a fairly regular and constant supply, such as the private hot-bath department; but others, for instance the washhouse, to which the women flock at regular hours, and the swimming baths, which are emptied and refilled occasionally, cause a very fluctuating demand on the water supply.

Appropriate Meter.

The amount of work to be done renders it imperative to use a meter of great durability; the rotary-piston type is therefore the best where all purposes are combined in the one establishment.

Swimming Baths only.

For a Swimming Bath only, the inferential meter should be used, the total consumption being comparatively low,

Appropriate Meter.

while the speed of flow is uniformly high. Swimming baths not only have to be filled at full bore, but, being below the ground level, entail a greater strain on the meter, by reason of there being no back pressure. It is advisable in such cases to reduce the size of the outlet by about half its diameter for a few inches of its length; this will not decrease the rate of delivery 5 per cent., and by creating just sufficient back pressure to support the working parts, will save the wear and tear of the meter 50 per cent.

Public Buildings, etc.

Public Buildings, Town Halls, Libraries, Museums, &c., contain urinals and lavatories which create a constant use

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of water throughout the day in fairly large volumes. The large cisterns with which they are usually furnished, and the number of water-fittings there are in which leakage may occur during the night, or at such times as the ordinary business of the place may be suspended, render it necessary to have a meter sufficiently sensitive to register fairly small flows. At certain times during the open or working hours the consumption may be very heavy; for instance, there may be lifts and organs to be worked in addition to the already large requirements for sanitary purposes.

Also, there are fire-hydrants which it is of the utmost importance should be supplied with water without material reduction of the main pressure, without check to the flow, and without concussion.

Appropriate Meter.

Rotary-piston meters should be employed for all such purposes—or at least in all but the smallest institutions, where the flow may be constant but very small, in which cases the reciprocating-piston meter should be used, but then of a larger size than would at first seem necessary, so that the fire-hydrant requirements shall not be compromised. Objections are sometimes raised on the score of want of control over the uses to which it may be put, to giving the fire-hydrant supply through a bye-pass; otherwise this may be advantageously done.

Fire hydrants on bye-passes.

Drinking Fountains, Water Troughs, etc.

Drinking Fountains, horse and dog Water Troughs, and very small public gardens or open spaces having a small fountain, either for ornamental or drinking purposes, should be metered in the same way, and for the same reasons, that urinals should be, *i.e.*, with meters of the reciprocating packed-piston type, attention being given to the fact that for fountains for ornamental purposes a meter with two pistons of unequal diameters will cause

Appropriate Meter.

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a variation in the height of the jet at every change of stroke.

Public Gardens, etc.

In Public Gardens, Parks, and Recreation Grounds where water is used for ordinary garden purposes, the rotary-piston meter is preferable, because the quantity used is considerable, and the rate of flow very varied.

Fountains, excepting those above referred to, using only very small flows, should be supplied by inferential meters, the pulseless delivery of which renders them well suited to the work. It is recommended that the meter should be of a size nominally larger than that of the supply pipe, in order that the full statical head may be available at the fountain. It is customary for fountains to play at intervals only; the durability of the instrument will not be taxed if this suggestion as to its size be carried out.

Flushing Drains. Appropriate Meter.

The water used for Flushing Drains is often taken from the water-carts or "hydrostatic vans." It has already been suggested under the head of "road watering" that the inferential meter is best adapted for this purpose. At other times water is used from the fire-plugs and paid for under agreement.

Trade Purposes.

"Trade Purposes" embrace such a multiplicity of uses that it is impossible to consider them individually without increasing the limits of this chapter to a tedious extent. But by considering the different combinations of conditions that exist in these many purposes it is easy to indicate the *most suitable instrument* for each of them—in other words, to "prescribe for the symptoms."

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Trade purposes in general necessitate use of large quantities of water.

Reviewing water-supply for trade purposes as a whole, it is evident from the very fact of water companies and corporations taking power to make separate and additional charges for such, that quantities in excess of those supplied under the rating system for household purposes are expected to be used. Broadly, therefore, the meter which combines in itself the greatest capacity of delivery, durability, continuance of initial accuracy, small cost of maintenance and first cost is the best: that is, the rotary piston meter is the best adapted for the measurement of water for trade purposes in general.

Appropriate Meter.

There is, however, such an enormous divergence in the nature of the work to be performed that there is occasion to utilise in a greater or less degree all the best classes of meters at present in the market.

Small quantities taken at high velocities and used immediately.

Inferential meters may be used where the consumption is comparatively small but taken at high or medium velocities and used immediately without going through any intermediate storage on the consumer's premises, so that there can be no possibility of the same quantity being gradually taken at a low velocity—at which the registration of an inferential meter would not be satisfactory—and stored until it is required.

E.g., Ship-supply.

For instance, water for ship-supply could be economically and satisfactorily measured by these instruments, as it is necessary that a ship's tanks should be filled quickly—which may take three or four hours through a 2 in. meter, passing perhaps 15,000 to 20,000 gallons—but then the water is shut right off, and there may be no further use for the meter for many days. The work done in a year would, under these circumstances, be little. In the case of a supply from which ships were being constantly watered a rotary-piston meter would be preferable.

Appropriate Meters.

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The inferential meter may be used for other similar work, but in no case to deliver into a cistern water not required for immediate use; otherwise a large quantity may be constantly obtained at slow speeds during the non-working hours absolutely unregistered.

Small flows constantly running.

Low-pressure meters can be used—where the particular risks attaching to this system (see page 19) are not considered of moment—for the constant supply of small flows, where the nature of the business renders large cisterns or tanks placed on the top of the premises supplied a convenience; also where the main-pressure is but little in excess of the height of the building. In other cases reciprocating (packed) piston-meters should be used where there is constant supply of water at very slow velocities into cisterns, whether or not varied occasionally by larger flows. Should the available working pressure be less than that due to twenty-five feet head, it is desirable to use the Kennedy meter, as it requires a much lower effective head than those meters which have cup-leather pistons.

Appropriate Meters.

Other conditions of supply for trade purposes.

The rotary-piston meter well meets all trade purposes, excepting some of those just enumerated. In all cases where the flow varies from the full maximum of the supply pipe down to small flows of seven to ten gallons per hour, it accurately discharges its duties of meter, and it supports the heavy work incidental to large supplies in a way that no other type can approach. Its great durability, continuance of initial accuracy, small cost of maintenance, render it by far the most reliable and economical instrument in supplying sugar refineries, breweries, boilers and condensers, "works" of every description, hotels, publichouses, etc. It is well adapted to measure the water used in working hydraulic cranes, lifts, etc., because of the exceptionally

Appropriate Meter.

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small head absorbed — *i.e.*, resistance offered—by the actuation of the meter and of the uniformly full port-area during the whole cycle of movement, so that whether it is placed on the inlet or on the outlet of the hydraulic apparatus, no check is offered to the flow, thus allowing the full "duty" to be obtained. A reciprocating meter is ill-adapted to this work, because the high velocity of flow suddenly passing not only strains the instrument but causes concussion and retardation.

Inferential meters generally "choke-bore" the flow, and thus reduce the power and speed of the apparatus; in addition to which, owing to the momentum imparted by the high velocity, the fans or turbines may continue revolving and registering after the flow has ceased.

Supply of feed water to boilers direct by utilising effective head.

There is one use of water for trade purposes which requires special notice—that is, the ingenious plan adopted in some towns which have a sufficiently high pressure in their mains, of supplying the feed-water to boilers direct by utilising the effective head, thus dispensing with both feed-pumps and injectors. In most places this method of boiler-feed is expressly prohibited by the waterworks regulations. The injection, in this way, of cold water into a boiler cannot be an economical arrangement for the consumer. But where it is done, it is very necessary to use a good reflux—or check—valve between the boiler and the meter, as it frequently happens in such cases either that the main pressure runs down or that the boiler pressure runs up, and then if the difference of pressure is in favour of the latter, the boiling water is forced back through the meter, probably with serious damage to the working parts. The meter should be placed as far as possible from the boiler to avoid overheating by conduction when no water

Appropriate Meters.

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is passing. The meter should be of the reciprocating-piston type for small boiler feeds, whether working direct or into a tank. For medium and large boilers the rotary-piston meter is preferable.

Appropriate Meters.

"Mixed Supply"—that is, water supplied for domestic and also for trade purposes through the same pipe—may be either constant or intermittent. If the former, the meter should be either of the reciprocating-piston, or of the rotary-piston class, according to the probability or not of very slow flows—of six gallons per hour and under—running during the greater part of every twenty-four hours. Such conditions are only likely in small houses, such as barbers', greengrocers', etc. In large residential business-houses these continuous dribbles are less likely, while there is almost certain to be a considerable demand for full-bore supply. If mixed supply be intermittent, then the inferential meter may be used for the smaller houses, and the rotary-piston for the larger; but it is wiser in all such cases to use that instrument which will pass the required quantity in the given time at the lowest first cost and cost of maintenance. (See Comparative Price Table, page 58.)

Various conditions of "mixed supply."

Appropriate Meters.

Mixed supply should be entirely by meter.

All "mixed supply" should be by meter, instead of partly by rate and partly by agreement as now usual. The change would be found considerably to the supplier's advantage. Small publicans, greengrocers, and other small traders who draw their trade water from their house cisterns, secure in nineteen cases out of twenty a great advantage over the supplier by paying a small agreed sum extra, instead of paying by measure. For example, photographers often keep a small stream of water running night and day through their washing-trays and use a much greater quantity in this way, when totalled up at the year's

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end, than would seem possible to anyone noticing the innocent-looking dribble going down the waste. Hair-dressers and barbers also use a quantity largely in excess of that provided for in the extra charge paid by them to meet that consumption.

Domestic Supply.

Domestic Supply by meter is a matter that involves great circumspection in the choice of the instrument.

It is possible to meter all such supplies with a minimum of trouble and a maximum of accuracy, by using the instrument adapted to the circumstances of each case or class of cases; but by ignoring the conditions of these supplies it is equally easy to obtain diametrically opposite results.

Three conditions of supply for Domestic Purposes.

The most important conditions that affect this selection are—first, whether the supply is to be constant or intermittent; and secondly, are cisterns to be retained or not?

With intermittent supply, cisterns are, of course, a *sine qud non*, but with constant supply they may be either retained or abolished, and before considering these three different combinations of conditions, it is worth while to briefly enumerate the *pro's* and *con's* of the cistern question with constant supply.

Advantages of cisterns.

The most cogent argument in their favour is the advantage of having a reserve to draw on in the event of the supply being temporarily interrupted. The annoyance and even danger of being suddenly deprived of all water would be almost insupportable. The number of purposes for which water is constantly needed testifies strongly to the great value of a reserve of this commodity in a house.

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Disadvantages of cisterns.

*On the other hand, great danger to health attaches to the use of cisterns because, in the first place, the great majority of people have the comfortable but utterly fallacious idea that because a cistern is daily replenished with fresh water it needs no other cleansing, whereas the bottom of a cistern—particularly where the outlet pipe is fixed an inch or two above the bottom, producing an amount of constantly stagnant water—becomes the resting place of the accumulated dirt and dust of years, to say nothing of its frequently providing a watery grave for adventurous but unfortunate mice and blackbeetles.

In the second place, the unscientific and insanitary way in which water closets are too often connected to cisterns allows the sewer gas to contaminate the water.

Cleansing of cisterns.

Cisterns should be regularly cleaned every three months, or at the very longest every six, otherwise there is grave risk of their originating fevers and other illnesses. The less a cistern is used the oftener it should be cleansed, as it is less scoured by the passing water.

Whatever conclusion may be arrived at in the abstract, the probability is that, actually, cisterns will be retained as, no matter how radical our politics, we are too conservative in the internal economy of our houses to readily acquiesce in so sweeping an abolition of existing institutions.

Constant Supply, with cisterns.

Constant Supply to houses with Cisterns involves a flow of greater or less quantities during the whole twenty-four hours; this will probably vary from the full flow due to the head and capacity of the meter down to the finest dribbles of half a gallon or a gallon an hour,—the small flows occupying by far the greater portion of the time.

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*A large proportion—varying from one-fourth to one-half—of the total daily consumption being drawn within the space of a couple of hours in the early morning, the presence of cisterns is valuable also as equalising the draught on the water-mains.

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Rate of flow at various times of the day.

The only periods of the day when the meter will be working full-bore is the morning, when baths, water closets and kitchen are all drawing (either simultaneously or with little or no interval), or at night when the same conditions may be present; then the water level in the cistern may be so lowered that the ball-cock is full open, but as the consumption becomes more intermittent and reduced it gradually closes: the flow will probably be reduced to a few gallons per hour, at which it will remain until bed time. Now, if no more water were drawn off and the ball-cock were sound, the flow could die off to nothing in an hour; but in nearly every house there is a slight leakage going on at one or more of the fittings—sinks, baths or closets; it may not be more than a drip at any one of them, but all these make in the aggregate an appreciable quantity, perhaps one or two gallons per hour or even more. [It would hardly be credited by those who have not made the experiment that six drops a second mean about one gallon an hour, or nine shillings a year at a shilling per thousand gallons]. Taking the consumption, under the above circumstances, at 100 gallons in the twenty-four hours, the times and rates of flows would be approximately as follows:—

Time.	Average rate of flow in gallons per hour.	Quantity passed in gallons.	Remarks.
11 p.m. to 7 a.m.	1	8	
7 a.m. „ 9 a.m.	20	40	..Baths, w.c.'s,
9 a.m. „ 7 p.m.	3·5	35	...Cooking, scrubbing, etc.
7 p.m. „ 11 p.m.	4·25	17	

Experiment showing average consumption per hour.

Subjoined is a tabular statement of the results given by a reciprocating packed-piston meter fixed on the supply

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to a house in which ten persons were living, four of whom were children.

The meter was read every hour between 6 a.m. and 10 p.m. for eight days. It was tested immediately before the experiment and found to register accurately within 2% plus or minus on all flows down to half-a-gallon per hour.

The supply was nominally "constant with cistern," but for some reason it was shut off in the small hours of some mornings and remained so until about 9 a.m. Hence the maximum registration occurred between 9 and 10 a.m., although the maximum draught from the cisterns was between 8 and 9 a.m.

*Average consumption of water per hour from 6 a.m. to 10 p.m. for eight days in a house containing 10 persons.**

BETWEEN	6	a.m.	and	7	a.m.	...	7	GALLONS.
„	7	„	„	8	„	...	4·5	„
„	8	„	„	9	„	...	13	„
„	9	„	„	10	„	...	36	„
„	10	„	„	11	„	...	20	„
„	11	„	„	12	„	...	11	„
„	12	„	„	1	p.m.	...	10·5	„
„	1	„	„	2	„	...	4·5	„
„	2	„	„	3	„	...	9	„
„	3	„	„	4	„	...	3	„
„	4	„	„	5	„	...	11	„
„	5	„	„	6	„	...	7	„
„	6	„	„	7	„	...	6·5	„
„	7	„	„	8	„	...	4	„
„	8	„	„	9	„	...	4	„
„	9	„	„	10	„	...	2·5	„
	Average per day					...	153·5	„

* Average per head per day, 15·3 Gallons.

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It will be seen that the supply passed into the cisterns at the following rates:—

Percentage of Total Supply.	Average rate per hour at which percentage was taken.
14·65	5 gallons per hour and under.
19·22	10 to 5 gallons per hour.
42·67	20 to 10 ,, ,,
23·46	Above 20 ,, ,,
100·00	9·59 gallons per hour.

In many individual hours there were of course moments when the average rate for that hour was much exceeded. For instance, between 9 and 10 a.m. the rate was sometimes 240 gallons per hour—but for a few minutes only. These quick flows were counterbalanced by a flow correspondingly slower than the average for the remainder of the hour.

The above tables show that, to register the whole or even the greater part of the water supplied under such conditions, it is imperative that the instrument used should be capable of measuring flows of the very lowest velocities.

The meter best suited to measure constant supply into cisterns.

Reciprocating packed-piston meters are, therefore, essential in all such cases, excepting only those places where the pressure is insufficient to overcome the friction incidental to this type of meter. These instances are few and far between, but they occur sometimes at the highest point of a district. Positive low-pressure meters are then most suitable, as they register every drop that passes and require an infinitely small head to actuate them.

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Such supplies, though nominally constant, are often practically intermittent, because during the periods when the draught on the mains is greatest the pressure in the mains becomes so reduced that the water recedes from the highest parts of the districts supplied, and only becomes available when the consumption has ceased or is reduced in the lower parts of the district.

Importance of registering the finest flows.

It is asserted, and is carried out in practice in some cases, that a high minimum charge is the great *desideratum* when domestic supply is paid for by meter, and that the non-registration of flows of low velocity is of little or no consequence.

But it seems demonstrable that this method deprives both supplier and consumer of the advantages that should be enjoyed under the meter system.

The employment of an instrument that does not register fine flows means that a large proportion—probably even the greater portion of the water used—is not paid for, because not registered, and, however high the minimum, the consumer will, more often than not, use or waste until the meter *shows* he has had the quantity covered by the minimum charge, so that all the unregistered water is absolute loss to the supplier. Further, he has no inducement to prevent waste, or, at least, such portion of it as is covered by the margin that often exists between his actual requirements and the minimum quantity paid for; he is obliged, as under the rating system, to pay for more than he needs.

The only advantage is that the meter acts as a sort of scare-crow and prevents a certain amount of deliberate waste after the minimum for the quarter has been once reached. Perhaps an instrument that made a good noise in working would serve the purpose well, as it would then act as a sort of conscience when the "still small voice" was silent.

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Sanitary minimum.

A fair minimum, however, is indispensable for domestic supply, for sanitary reasons; as much water being required, for instance, for sewage purposes by six people living in a house costing £20 a year as by six persons living in a house worth £200 a year. But in order to secure to consumer and supplier alike the full benefits of the meter system, the sanitary minimum should be kept to the very lowest point consistent with its purpose, and a meter should be used that would correctly register all the water used.

Constant Supply without cisterns.

Appropriate Meters.

The rotary-piston meter is preferable for "Constant Supply without Cisterns," as it has a larger and more constant delivery than any of the other types, while its registration on fine flows is too good to tempt the consumer to dishonesty, by allowing water to be run slowly into baths or tubs, etc., without registration, as is done with inferential meters. But where the number of consumers' supplies through one meter is large, as in most Continental towns, the inferential meter may also be used with good results. In such cases very small flows are so rare as to be negligeable quantities. Most reciprocating-piston meters, in addition to giving a reduced flow, which means annoyance and waste of time to those drawing the water, are apt to cause concussion when working at full bore, which is injurious to the fittings, straining and making them leak: they are also more costly.*

* Since the above was written, a paper by Mr. Henry Gill, the engineer and manager of the Berlin Waterworks, entitled "The Sale of Water by Meter in Berlin," has been read at the Institution of Civil Engineers. Mr. Gill mentions that Berlin is supplied with water entirely on the meter system, the supply having been found inadequate under the rating method; the meters are all inferential; the supply is constant without cisterns. Owing to the fact that each house supplied contains a number of families living in flats, each meter supplies water for an average of sixty-seven people; small flows are therefore very exceptional. The results obtained appear very satisfactory.

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Intermittent Supply.

When the Supply is Intermittent the only consideration of importance in selecting the meter is that it shall have a sufficient delivering capacity to fill the cisterns or tanks on the premises supplied, in the twenty or thirty minutes during which the water is turned on from the mains. It does not matter whether the meter be inferential, reciprocating-piston, or rotary-piston; the flow being all full-bore, so far as performance goes there is nothing to choose. Decision should be governed entirely by price, and that meter selected which, regardless of type or nominal size, can be most cheaply bought and maintained to deliver the required quantity in the given time with efficient registration.

Appropriate Meters.

Summary of purposes and most suitable type of meter.

Summary of the different purposes for which Water is supplied by quantity, and of the type of meter best adapted to the requirements of each.

Purpose.	Type of Meter.
Trunk or district mains ...	Rotary piston.
Ditto, to detect waste ...	Waste-water meters.
Road watering	Inferential.
Urinals	Reciprocating packed-piston.
Public baths	Rotary piston.
,, swimming bath only ..	Inferential.
Public buildings, Town Halls, Libraries, Museums, &c....	Rotary piston.
Ditto, with small consumption	Reciprocating packed-piston.
Drinking fountains and horse troughs	Reciprocating packed-piston.
Small open spaces, with miniature fountains ...	Reciprocating packed-piston.
Public gardens, parks, and recreation grounds ...	Rotary piston.

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Purpose.	Type of Meter.
Fountains	Inferential.
General trade purposes ...	Rotary piston.
Trade purposes requiring small intermittent supply without cisterns	Rotary piston, or inferential.
Trade purposes requiring constant supply at very low velocities	Reciprocating packed-piston.
Some special trade purposes (p. 44)	Low pressure.
Hydraulic power	Rotary piston.
"Mixed supply" to small consumers	Reciprocating packed-piston.
"Mixed supply" to medium and large consumers ...	Rotary piston.
"Mixed supply," intermittent	Inferential or rotary piston, according to cost.
Small boiler supply... ...	Reciprocating packed-piston.
Large boiler supply ...	Rotary piston.
Domestic supply, constant, with cisterns	Reciprocating packed-piston.
Domestic supply, constant, without cisterns	Rotary piston or inferential.
Domestic supply, intermittent	Reciprocating piston, rotary piston, or inferential, according to cost.

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CHAPTER IV.

THE PRICES AND THE VALUES OF WATER METERS.

THE price of a meter is a point that is naturally of great weight with purchasers, but it is doubtful whether many do not entirely ignore or misapprehend the true measure of price. It must be gauged by three distinct considerations, and not by the nominal size by which the instrument may happen to be distinguished in the manufacturer's catalogue. These considerations are :—

The true measure of price gauged by three considerations.

1. Is the meter *suitable* for the particular purpose for which it is required? (See chap. III.)
2. What is its delivering capacity in relation to its price?
3. What is its cost of maintenance?

The meter must be suited to the work.

To refer briefly to these points *seriatim*. With regard to the first and most important point it will be seen that if a meter be put to work for which it is unfitted, so that loss of registration occurs, the cost to the supplier is increased by the amount of that loss.

For instance, an Inferential meter, costing say £2, is put in at an urinal to measure a constant dribble: the result assuredly being the loss of registration of three-quarters of the consumption—or, say, about £2 15s. per annum. In one year, therefore, the cost of that cheap Inferential meter will have amounted to more than the cost of the more expensive, but suitable, Positive meter. Similarly

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it may be shown that a Positive meter, if put to work for which an Inferential is better adapted, has its already higher price augmented.

This paramount condition having been satisfied, the question then is; what delivering capacity has the meter at a given head, and what is the highest speed at which it can be worked without suffering damage? These capacities must be considered in relation to the cost of the instrument.

Delivering capacity, and not nominal size criterion of first-cost.

For instance, there may be found in one manufacturer's catalogue a meter described as ¾-inch—that is with ¾-inch diameter inlet and outlet—which is priced at £4 10s., and stated to pass 1000 gallons per hour at 100 feet effective head, while in the price list of another maker a meter of ¾-inch nominal size is priced at £5 10s., with a capacity of 1750 gallons per hour at the same pressure; the corresponding figures for the ½-inch of the latter make being £3 17s. 6d., and 1000 gallons. As a general rule when a meter has to be fixed, it is not a question of nominal size but of *quantity of water to be delivered per hour;* and it is evident that in all such circumstances the ½-inch of the latter maker would be as adequate for the duty as the ¾-inch of the first. So if the meters of the two makers were compared by size the former would appear the cheaper, but if by capacity the latter.

Again there may be—indeed are—two different meters of the same *nominal* size, which let us distinguish as A and B:—

"A" costs £5 5s., and will deliver 1610 gallons per hour, at 50 ft. effective head. "B" costs £2 7s., but will only deliver 600 gallons at the same head. "B" would be the cheaper meter only in those few cases in which a certain nominal size of meter was specified without regard to capacity of delivery. In other cases "A" would be

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the cheaper, as it delivers 306 gallons for every pound sterling of cost; while "B" only delivers 255 gallons for the same capital expenditure.

Insufficient data as to delivering capacity given by makers.

Unless other data be used than the particulars given in the catalogues of the manufacturers, it is impossible to compare the prices of different meters by the light of their capacity of delivery. Some makers give no figures as to the delivering capacity of their meters; some give the quantities delivered, but omit to say at what effective head the results are obtained; others, again, give the quantities and the heads, but do not describe the connections; while all the data necessary are given by one or two firms only.

Tests made to supply above deficiency.

In order to better illustrate the great difference in the price-value of meters, six meters of different manufacture—four positive and two inferential, all of them of types in general use—of each size, from ¾-inch to 1-inch, were tested at certain waterworks. The following Tables are compiled from the results:—

COMPARATIVE PRICE-VALUES OF CERTAIN METERS.

Tabulated results of tests.

Type of Meter.	Delivering Capacity in gallons per hour per £1 of cost.
½-INCH POSITIVE METERS.	
Reciprocating packed-piston, A ...	136·
,, ,, ,, B ...	155·3
,, ,, ,, C ...	71·2
Rotary piston	260·7
½-INCH INFERENTIAL METERS.	
Rotary turbine	150·6
Rotary fan	186·5

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Type of Meter.	Delivering Capacity in gallons per hour per £1 of cost.
¾-inch Positive Meters.	
Reciprocating packed-piston, A ...	161·1
„ „ „ B ...	205·1
„ „ „ C ...	68·7
Rotary piston	290·5
¾-inch Inferential Meters.	
Rotary turbine	294·5
Rotary fan	321·
1-inch Positive Meters.	
Reciprocating packed-piston, A ...	170·1
„ „ „ B ...	225·5
„ „ „ C ...	70·4
Rotary piston	311·7
1-inch Inferential Meters.	
Rotary turbine	437·
Rotary fan	344·6

Comparative price-value of positive and inferential meters.

It is generally accepted that inferential meters are cheaper than positive, but it will be seen from the above figures that the comparison of cost, based on delivering capacity, is dependent on the size. Of the above ½-inch meters, a positive is the cheapest. Of the ¾-inch there is but little difference between the two classes; while of the 1-inch the difference is much in favour of the inferential.

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It is worthy of note that of these 1-inch meters the cheapest inferential is six times cheaper than the worst of the positive.

Suitability for purpose paramount to price-value.

It does not follow, that because in this mode of calculation, an inferential in the larger sizes, and a positive in the smaller comes out the cheaper, therefore for all large work an inferential meter should be used, and for all small work a positive. As is shown elsewhere, other factors must be taken into consideration, viz., cost of maintenance, and above all—indeed, including all—suitability for the purpose for which the meter is intended (see chapter III.).

Positive meters have greater delivering capacity than inferential meters.

The average flow in gallons per hour

		Of the ½-inch Meters was—			
Positive...	...	767	Inferential	...	402
		Of the ¾-inch Meters—			
Positive...	...	1148	Inferential	...	843
		Of the 1-inch Meters—			
Positive...	...	1648	Inferential	...	1444

The average flow of the positive meters would have been much in excess of that indicated by the above figures, but for the meters of one manufacture which gave an extraordinarily small delivery.

Of all the ½-inch meters, the best—a positive—delivered 1108 gallons per hour. Of all the 1-inch meters, the worst—also a positive—delivered but 739 gallons per hour; in other words, it would need one and a half of the 1-inch meters of the latter make to do as much work as one ½-inch meter of the former.

The greatest difference in the quantity of water delivered

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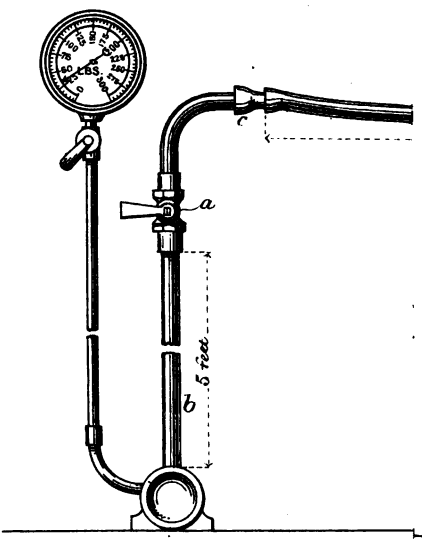
SKETCH, SHOWING



½-IN. METI

a 1-in. full-way
b 1-in. iron barı
c 1-in. to ½-in. ı
d 1-in. rubber t
e ¾-in. pipe, 6 i
f ½-in. Meter.

Face p. 60.

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by meters of the same nominal size occurred with the ½-inch meters, one of which passed 1108 gallons in an hour, while another only passed 320 gallons in the same time. This great difference cannot be regarded as peculiar to the one size, as the ¾-inch and the 1-inch meters of different types varied to an almost equal extent.

It is granted that the tests upon which the above tables are based were not made in the elaborate and laborious way from which scientifically accurate generalizations may be deduced.* But they are accurate enough for practical purposes.

Cost of maintenance

The remaining point affecting the question of price is "cost of maintenance." Let it be assumed in order to more easily appraise the importance of this element that the first cost (price), gauged by capacity, of certain different kinds of meters is equal, but that the cost of maintenance is 12 per cent. in one, and 3 per cent. in another. In ten years the difference of cost will be equal to 90 per cent. of the original price. This may be thought a fanciful case for which no justification could be found in actual practice, but the reverse is the fact. Now and again by a singularly adverse concatenation of circumstances cases occur which show a still more startling difference of cost of measurement. For example, a high-priced meter, having normally a high rate of maintenance, is put to a purpose to which it is ill adapted—say, to work full-bore at a high effective pressure with little counter-head—consequently it is always "in hot water," its already high maintenance being increased 50 per cent. Its price being originally, say, £10, it may cost to

Importance of reducing it to the lowest possible.

* Had pipe-friction been eliminated, for instance, the results would have been slightly more favourable to the positive meters, because those giving the greatest deliveries must necessarily have suffered the greatest loss of head from the friction in the inlet and outlet pipes.

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maintain, during ten years, £15 or £20. The measurement of water would be a decidedly costly process. Thus:—

Interest on capital and amortisation of first cost for ten years at 7½ per cent. per annum	£7 10 0
Cost of maintenance, which in the above case might very possibly amount to 17½ per cent. per annum, for ten years ...	£17 10 0
	£25 0 0

Or it would cost £2 10s. per annum to keep going a meter originally worth £10. The supplier would thus be expending 25 per cent. per annum, in return for which he would not obtain from the consumer more than 15 per cent. per annum as meter-rental. That which properly managed should be a source of income would thus become a cause of recurring loss.

Variation of cost of maintenance.

Cost of maintenance is given in manufacturers' catalogues at figures varying from 7½ per cent. to 2 per cent. on the list price of meters; but it often mounts up on a water company's books to 15 per cent. or even 17 per cent. Most manufacturers express their willingness to contract with companies or corporations to keep their meters in repair at from 2 per cent. to 7½ per cent. It is submitted that it is a wise course for engineers to adopt this contract system.

But if this be not done it is well to send the "leading hand" or foreman of the repairing-shop to the manufacturer's for a few days' instruction—which in nearly every case would be willingly given—as a proper understanding

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of the working and manipulation of the apparatus is manifestly to the interest both of manufacturer and client, and would go far towards minimising the cost of maintenance.

Summary of the measure of price.

These three conditions having been considered, the whole matter may be summed up thus:—What is the cost per annum of measuring the water supplied to a particular consumer as against the amount received from him as meter-rental? Or, what is the cost of measuring per thousand gallons supplied? The figures to be considered being interest on first cost of meter, plus percentage for amortisation of first cost, plus cost of maintenance in relation either to time or quantity measured.

Companies or corporations using a large number of meters may make or mar their earnings by the choice of suitable or non-suitable meters with a correspondingly high or low maintenance-cost.

The "duty" obtained from pumping-engines which pass the water into the company's mains is always an element of admitted importance; why not equally so the "duty" of the meters which pass it out?

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CHAPTER V.

THE DELIVERING CAPACITY OF METERS.

A method of determining the size of instrument required.

THE paucity of the information supplied by meter makers in general as to the respective delivering capacities of their meters must often render it a difficult matter for water-engineers to know what sized instrument to select in cases in which a specified quantity of water has to be delivered. The writer is unfortunately precluded, by obvious reasons, from giving the detailed information as to the delivering capacities of specific meters, which would afford a means of overcoming this difficulty. In one case only is he at liberty to publish the necessary data. Engineers when fixing meters of other makes to deliver exact quantities, must obtain from the manufacturers information corresponding to that given in Table I. The data thus obtained will, it is hoped, form in conjunction with those comprised in these pages, a ready means of making the calculation. Although meters of different types, but of the same nominal size, vary greatly in their delivery, it may be taken as a general truth that the service pipe rather than the meter is the cause of a feeble supply in a house, where there is known to be a fair pressure in the street main. In order to provide a means of easily determining the proportion of loss of head due to each, the following tables, founded partly on certain well-known hydraulic laws and partly on water meter experiments, are given.

The laws referred to are these :—

1. A. The rate of delivery of water through a pipe will be in direct proportion to the square root of the head.

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B. Conversely, the head required will be directly as the square of the rate of delivery.

In other words fluid friction in a pipe varies as the square of the speed.

2. The loss of head caused by fluid friction in pipes of different diameters is in the inverse ratio of the fifth power of their diameters.

Mr. Thomas Box gives in his "Hydraulic Tables" the following formula to determine the loss of head by friction in pipes:—

$$H = \frac{G^2 \times L}{(3\ d.)^5}$$

In which d = diameter of pipe in inches.
G = gallons per minute.
H = head of water in feet.
L = length of pipe in yards.

The appended table gives the results of a series of tests made to ascertain the actual delivery of the Kent Meter when working without any retardation of flow caused by inlet or outlet pipes.

TABLE I.

FREE DELIVERY OF THE KENT METER.

Diameter of Inlet of Meter.	Effective Head in Feet.	Rate of Delivery in Gallons. Per Minute.	Per Hour.
½"	49	18·4	1,108
¾"	49	34·6	2,087
1"	49	54·1	3,248
1½"	25	66·3	3,981
2"	25	108·5	6,510
3"	25	191·3	11,479
4"	25	299·7	17,983
6"	25	483·7	29,021

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The loss of head caused by fluid friction in pipes, bends, cocks, etc., is the other factor to be considered.

Absorption of head by pipe-friction.

Opposite is a table giving this loss in pipes of various diameters. The figures are calculated from Box's Hydraulic Tables and from the formula given above. It will be seen that the loss of head in each size of pipe is calculated at the same speed of flow as is given in Table I. for the meter of the corresponding size. The loss of head due to the same speed in a pipe one size larger in diameter is also given in each case, as it frequently happens that part or all of the service pipes are larger, rather than smaller, than the nominal sizes of the meter to or from which they lead.

It is assumed that the pipes are led from mains of a diameter so much larger that the loss of head in the main itself, caused by the draught to the pipe, is practically *nil*.

Bends and elbows.

The head absorbed by bends and elbows is a matter that more often concerns the consumer than the supplier, but should it be necessary to consider the point, it will be found safe to reckon a short bend, *i.e.*, nipple and elbow, as pipe of the same size but half as long again. The change of the direction of the current in long bends causes so slight an increase of loss of head that it may be disregarded for the purpose in question.

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Table II.

Loss of Head through Friction in Pipes of Various Diameters.

Calculated according to Mr. Thomas Box's formula (page 65).

Rate in Gallons per Min.	Diameter of Pipes in Inches.							
	½-in.	¾in.	1in.	1½in.	2in.	3in.	4in.	6in.
	Head of Water consumed by friction in pipe 10ft. long.							
18·4	147·1	19·4						
34·6	...	68·5	16·3					
54·1	...	...	39·7	5·23				
66·3	...	...	...	7·8	1·86			
108·5	...	...	...	...	4·99	·658		
191·3	...	...	...	...	...	2·05	·485	
299·7	...	...	...	...	...	...	1·19	·157
483·7	...	...	...	...	...	...	...	·409

The above figures have been confirmed by experiments. Slight variations were observed in one or two instances, but were found to be due to the pipes not being exact to their nominal size.

Variations from nominal size of pipes.

Wrought-iron barrel is generally rather less in diameter than its proper size. A great increase in friction, especially in the smallest sizes, would be thus caused. On the other hand it is very usual to find so-called ½-inch *gas*-barrel quite ⅝-inch in diameter. Other sizes of gas-barrel vary much less, but all tend to be larger than the nominal size.

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Absorption of head by stop-cocks, stop-ferrules and screw-down valves.

Stop-cocks, stop-ferrules, and screw-down valves are very important factors in calculating rates of delivery of water to consumers' premises. These fittings are almost always placed between the supplier's main and the meter, and very necessary they are. Nevertheless the loss of head thus occasioned is not to be overlooked in calculating the delivery due to a given head. What the loss represents in feet at any given speed it is impossible to estimate by any general rule, in view of the almost infinite variety of patterns of these fittings. No doubt many are, as they are represented to be, "full-way" or "full-bore," but even then the course of the water is so twisted and diverted, or the shape of the stream so distorted and altered, that the flow can but be compromised to a considerable extent.

To give some slight guide, experiments were made, with the following results :—

A ½-inch "full-way" plug stop-cock absorbed as much head as would 2·7 feet of iron barrel of ½-inch diameter.

A ½-inch screw-down valve equalled, in head absorbed, 3·5 feet of the above pipe, and a ½-inch ordinary stop-ferrule equalled 4·4 feet of the same pipe. Similar results would probably be obtained with the ¾-inch and 1-inch fittings, but it must be borne in mind that the figures would tend to differ for each one of the many different kinds used.

Rates of flow corresponding to higher and lower heads.

The next and last table is so arranged that, given any rate of flow and the head in feet producing it, the flow due to any higher or lower head can—*cæteris paribus*—be instantly ascertained. The figures can be read either as gallons per minute, or as gallons per hour, of course bearing in mind that the answer will be in the same terms as the data.

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TABLE III.

Approximate Rates of Flow corresponding to Higher and Lower Heads.

Feet Head	10	20	30	40	50	60	70	80	90	100	125	150	175	200	250	300
Square Root of Head ...	3·16	4·47	5·47	6·32	7·07	7·74	8·36	8·94	9·48	10	11·18	12·24	13·22	14·14	15·81	17·32
Rate of Flow in Gallons per minute, or in Gallons per hour.	11	15	19	22	24	27	29	31	33	35	39	42	46	49	55	60
	12	17	21	25	28	30	33	35	37	40	44	48	52	56	63	69
	15	22	27	31	35	38	41	44	47	50	55	61	66	70	79	86
	18	26	32	37	42	46	50	53	56	60	67	73	79	84	94	103
	22	31	38	44	49	54	58	62	66	70	78	85	92	98	110	121
	25	35	43	50	56	61	66	71	75	80	89	97	105	113	126	138
	28	40	49	56	63	69	75	80	85	90	100	110	118	127	142	155
	31	44	54	63	70	77	83	89	94	100	111	122	132	141	158	173
	37	53	65	75	84	92	100	107	113	120	134	146	158	169	189	207
	44	62	76	88	98	108	117	125	132	140	156	171	185	197	221	242
	50	71	87	101	113	123	133	143	151	160	178	195	212	226	252	277
	56	80	98	113	127	139	150	160	170	180	201	220	237	254	284	311
	63	89	109	126	141	154	167	178	189	200	223	245	264	282	316	346
	71	100	123	142	159	174	188	201	213	225	251	275	297	318	355	389
	79	111	136	158	176	193	209	223	237	250	279	306	330	353	395	433
	87	122	150	174	194	213	230	246	261	275	307	337	363	388	434	476
	95	134	164	189	212	232	250	268	284	300	335	368	396	424	474	519
	110	156	191	221	247	270	292	312	331	350	391	428	462	494	553	606
	126	178	218	252	282	309	334	357	379	400	447	489	528	565	632	692
	142	201	246	284	318	348	376	402	426	450	503	550	594	636	711	779
	158	223	273	316	353	387	418	447	474	500	559	612	661	707	790	866
	173	245	300	347	388	425	459	491	521	550	614	673	727	777	869	952
	189	268	328	379	424	464	501	536	568	600	670	734	793	848	948	1039
	205	290	355	410	459	503	543	581	616	650	726	795	859	919	1027	1125
	221	312	382	442	494	541	585	625	663	700	782	856	925	989	1106	1212
	237	335	410	474	530	580	627	670	711	750	838	918	991	1060	1185	1299
	252	357	437	505	565	619	668	715	758	800	894	979	1057	1131	1264	1385
	284	402	492	568	636	696	752	804	853	900	1006	1101	1189	1272	1422	1558
	316	447	547	632	707	774	836	894	948	1000	1118	1224	1322	1414	1581	1732
	395	558	683	790	883	967	1045	1117	1185	1250	1397	1530	1652	1767	1976	2165
	474	670	820	948	1060	1160	1254	1340	1422	1500	1676	1836	1982	2120	2370	2598
	553	782	957	1106	1237	1354	1463	1564	1659	1750	1956	2142	2313	2474	2766	3031
	632	894	1094	1264	1414	1548	1672	1788	1896	2000	2236	2448	2644	2828	3162	3464

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The rules and tables being thus set forth, it only remains to show the method of applying them.

Example demonstrating use of tables and rules.

Let it be supposed that it is desired to find the delivering capacity of a 1-inch Kent Meter fixed on 30 feet of 1-inch pipe leading from a 12-inch main. Let it be supposed that the pressure in the main is equal to 125 feet head and that it will remain constant when fully supplying the 1-inch pipe. Also that the water has to be delivered at a height 25 feet above the level of the main. A 1-inch stop-cock is fixed between the meter and the main, and another between the meter and the point of delivery.

It is seen by Table No. 1 that a 1-inch Meter delivers 54·1 gallons per minute with an effective head of 49 feet: by Table No. 3 that a 1-inch pipe, 10 feet long, passing 54·1 gallons per minute, absorbs 39·7 feet head. Therefore, when passing water at the rate of 54·1 gallons per minute, the head absorbed by 30 feet of 1-inch pipe, plus two stop-cocks each equal to, say, 4 feet of pipe, will be—

	39·7
Multiplied by 3 + ·8	3·8
	= 150·86
+ Head for meter	49
	= 199·86

That is, with conditions of connection given as above, a head of 199·86 feet would be required to produce a delivery of 54·1 gallons per minute.

Now the head actually available is 125 feet − 25 feet counter head, lost in rising to the tank level, = 100, and, according to Law 1A, as the square root of the supposed head is to the square root of the actual head

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so is the supposed delivery to the actual delivery; therefore—

$\sqrt{199{\cdot}86} : \sqrt{100} :: 54{\cdot}1$ gallons per minute : actual delivery.

$14{\cdot}14 : 10 :: 54{\cdot}1$ „ „ „ „ „

$\frac{10 \times 54{\cdot}1}{14{\cdot}14} = 38{\cdot}26$ gallons delivered per minute by the Kent Meter.

Before proceeding further, it will be well to explain the use of Table No. 3, which will save the trouble of the above calculation. To use it, find under the supposed head the supposed rate of flow; then on the same horizontal line, under the actual head, will be found the actual rate of flow.

Should it happen that the exact figures of the supposed rate of flow are not given in the table, a sufficiently exact result may be obtained by taking the nearest figures and making a corresponding allowance in the figures representing the actual rate of flow.

In the present case, under the supposed head of 200 feet, 56 gallons per minute is the nearest rate of flow to that given (54·1); then on the same horizontal line under the actual head of 100 feet is given the actual flow of 40 gallons per minute—which, after making a corresponding allowance, would be reduced to about 38 gallons.

Should this delivery be insufficient for the requirements, a larger pipe certainly, and a larger meter possibly, must be substituted.

If it be desired to ascertain the necessary size of service pipe, and meter of any other make, it can be done on the lines above indicated, but, as before stated, data corresponding to those given in Table I. must be first obtained from the manufacturer of the particular meter to be used.

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CHAPTER VI.

HINTS AS TO SELECTING, FIXING, AND MAINTAINING WATER METERS.

In selecting a Meter,

Always put in a meter large enough for the work to be done, so that there is a margin between the utmost that can be demanded of it and the limit of its capacity.

Never use a reciprocating-piston meter for the constant measurement of full-bore flows at high effective heads.

Always use a reciprocating packed-piston meter for constant measurement of flows of very low velocities.

Never use a meter with cup-leather pistons where there is a smaller effective head than 25 feet, nor where it is likely to be idle for three or four days consecutively in hard water.

Always use a rotary-piston meter for the constant measurement of high-velocity flows, also when alternated with low-velocity flows.

Always use an inferential meter for the measurement of occasional high-velocity flows only.

In Fixing a Meter,

Set it level.

Do not spring or strain it.

If attached to a new main or pipe, flush the latter through before attaching the meter.

Drain all pits in which meters are to be placed.

Let the surface-box be large enough to allow the meter to be easily got at.

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Make provision for protecting the meter from frost, *i.e.*, let it be accessible enough to allow of its being thoroughly wrapped round with hay-bands or straw.

Allow no lead cuttings, iron filings, or red lead to get into the meter when making the connection.

See it started before you leave it.

To Maintain a Meter in Good Order,

Reading.

Read it monthly, if possible. If the registration shows a falling off on the average consumption, let the inspector make a rough test by turning on a tap on the service and observing whether the meter appears to be running correctly; if it is then doubtful, have the meter removed.

Periodical Examination.

Do not let meters remain until they are evidently out of order, which probably means a considerable and constant loss of registration for some time previous to the discovery, but let it be a rule that meters be taken out, for testing and examination, when they have been in a certain time—say one, two, or three years, according to the nature of the water and its effect upon the particular meter in use—and also when they have passed a certain quantity in any less time. The following table is suggested as a guide:—

A	$\frac{3}{8}$″ meter should be taken out for testing and examination when it has, in less time than its usual "session," passed	...	500,000	gallons.
	$\frac{1}{2}$″ Ditto	Ditto ...	1,000,000	,,
	$\frac{3}{4}$″ Ditto	Ditto ...	2,000,000	,,
	1″ Ditto	Ditto ...	3,500,000	,,
	$1\frac{1}{2}$″ Ditto	Ditto ...	5,000,000	,,
	2″ Ditto	Ditto ...	7,500,000	,,
	3″ Ditto	Ditto ...	15,000,000	,,
	4″ Ditto	Ditto ...	25,000,000	,,
	6″ Ditto	Ditto ...	40,000,000	,,

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These quantities would be modified by the type of meter used, and by the pressure and nature of the water—a high pressure and gritty water, of course, causing more wear and tear than a medium pressure and clean, soft water. Experience will soon suggest to what extent the above periods and quantities should be modified.

Maintenance by contract.

If the waterworks be within reasonable distance of the meter-manufacturer's works it is advisable to contract with him for the maintenance of the meters, which can be done at from two per cent. to seven and a-half per cent. on the list price, according to the different kinds.

If the distance be so great that cost of carriage would be prohibitive, it is well to have at least one man—the foreman or leading hand—thoroughly well acquainted with the construction and peculiarities of the meters in use. A supply of spare parts should be kept in stock, so that repairs or renewals can be promptly effected.

Testing.

Before putting a meter to work it is advisable to give it a short run, both at high and low velocities, in the testing-shop of the waterworks, or even if there be no testing apparatus, still to connect it in any available way to at least ascertain that it passes water and registers.

Although this is particularly necessary when meters have been kept in store a long time, it is a wise precaution even with meters just received from the makers, as although they are properly tested at the works there is a possibility—remote though it is—of injury afterwards, when they are opened to put the register to zero, and also in course of transit.

Testing apparatus is indispensable where any considerable number of meters are in use. This can be efficient without being elaborate or costly, and should consist of the following items—

Testing Apparatus.

A one-hundred gallon upright tank with a gauge-glass

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running from top to bottom graduated in gallons and decimals of gallons. The tank should be cylindrical and preferably of not more than 27 inches in diameter. This gives an easily discernible difference of level in the gauge-glass to a tenth of a gallon, which a tank of larger area does not do. A two-inch waste-cock will allow of the tank being quickly emptied.

A testing bench, arranged so that small meters (up to an inch and a half) can be readily clamped water-tight between flanges, one connected with the supply and the other with the outlet pipe, which last should be led to the top of the tank and there terminate in a bib-cock with a screwed nose, on to which a cap containing a perforated disc should be affixed. If the pressure in the testing-room is practically constant, the flow through the perforation of such a disc will also be constant; so that a set of discs can be kept, each stamped with the quantity it will pass per hour, say one each for 2, 5, 10, 20, and 50 gallons per hour respectively. Thus when a meter has to be tested on any given slow velocity—and 10 gallons per hour is that most generally adopted for meters up to 1 in., but this should obviously depend on the purpose for which the meter is to be used—the proper disc can be applied and the flow required is at once obtained, instead of wasting half an hour in guessing at it by opening and closing the cock. When full flows are desired, the cap is screwed off. Pressure-gauges, marked in feet and in pounds, should be fixed both on the inlet and outlet pipes. These pipes should be either 1 in. or $1\frac{1}{2}$ in. in diameter.

A 3-in. main should be run into the testing room for use with 2-, 3-, 4-, 6-inch and larger-sized meters, with which it can be readily connected by means of fire-hose and spring-couplings. Standard flanges of the different

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sizes should be kept with the mate-couplings affixed. To test a large meter these flanges can be bolted on and then be connected in a few seconds to the 3-in. main on one side and to the tank on the other by the hose and spring couplings. A great saving of time is effected by not having to get the meter, which perhaps may weigh a ton or more, into a particular position, as is necessary when rigid pipes and couplings are used.

A 500-gallon graduated tank is desirable if there is a certain number of large meters to be considered. Otherwise it is quite possible, by using care, to obtain accurate tests with the 100-gallon tank. The tank can be filled several times over, should there be a difficulty in accurately reading so small a quantity on the dial.

A screw wrench, a full set of spanners, two or three screw-drivers (large and small), and sealing appliances complete the list.

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CHAPTER VII.

WATER METER REGULATIONS, RENTS, AND CHARGES.

THE following regulations are compiled from those in force at many of the principal English waterworks. The scale of meter-rents is averaged from a number; there was, however, little difference between any of the schedules.

Provision and fixing of meter.

1. All meters will be provided by the Authority,* and fixed by them in such positions as they shall determine, but the cost of fixing, including the necessary ferrule, pipe from the street-main, and stop-cock—all of which will be supplied and fixed by the Authority—is to be paid by the consumer.

Accidents.

2. The Authority will not be responsible for any accidental stoppage, deficiency, or want of supply arising from frost, drought, or other unavoidable cause or accident.

Damage.

3. The Authority will not be in any way responsible for any damage done to the consumer's property through accident to the meter or its connections.

Meter rentals.

4. All meters will be maintained and repaired to the extent of ordinary wear and tear at the following charges, which also include the rent:

Size of Meter.	Rent and Maintenance Charge per Quarter.	Size of Meter.	Rent and Maintenance Charge per Quarter.
	s. d.		£ s. d.
⅝-inch bore	2 0	2-inch bore	0 9 0
½ " "	3 0	3 " "	0 15 0
¾ " "	4 0	4 " "	1 5 0
1 " "	5 0	5 " "	1 15 0
1½ " "	7 0	6 " "	2 5 0

* NOTE.—For "Authority," read Board, Committee, Corporation, Company, as the case may be.

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Repairs.

5. The cost of repairs necessitated by injury from fire, frost or accident must be paid by the consumer. The cost of any repairs required by reason of faulty material or construction will be defrayed by the Authority. All repairs will be executed by or under the direction of the Authority.

Notice as to discontinuing supply.

6. The rent of any meter shall continue to be charged until the consumer has given written notice to the Authority that a supply of water is no longer required.

Access.

7. All meters will be under the sole control of the Authority which shall have access thereto at all reasonable times.

Removal of meter.

8. The Authority may, whenever it pleases, remove any meter for the purpose of testing the accuracy thereof, or for examination or repairs, or in order to substitute it by another, and also in case of the discontinuance of the supply.

Mal-registration.

9. Should it be found that a meter is not registering correctly—whether it has stopped entirely or not—the charge for water taken thereby shall be assessed at the average for the period corresponding to that affected by the imperfect registration.

Testing at consumer's request.

10. The consumer may request the Authority to test his meter should he dispute the registration. The cost of testing must be borne by the consumer should the meter prove to be less than 5 per cent. fast, but if it be 5 per cent. or more fast, the cost will be defrayed by the Authority, and the ascertained overcharge be refunded *pro ratâ* for the two preceding quarters. The charge for testing shall not exceed 15 per cent. of the cost price of the meter.

Connections of meter.

11. Every meter must be fixed on a separate and distinct inlet leading direct from the Authority's main. No branch-pipe, drawing-cock, or other outlet, may be fixed

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upon this inlet pipe to the meter unless with the written consent of the Authority.

12. The consumer shall in no way interfere with or disconnect the meter or its fittings.

The price charged per thousand gallons for water supplied for trade purposes naturally varies according to the cost of procuring it in the first instance; it is therefore impossible to give any average charge that will suit every place. It is usual to have a sliding scale—the larger the quantity the smaller the price. But the rate for each step in the scale should only be operative between its limits. That is, when the quantity entitles the consumer to pay at a lower rate, such reduction should only apply to that part of the total consumption which is in excess of the next higher priced step in the scale.

Sliding scale of charges.

Otherwise, if the reduced rate applies to the whole quantity, it may happen that the consumer pays less if he uses more water.

For example, if a rate were 8d. per 1000 gallons up to 200,000, and 7d. up to 300,000, the price would be less for 225,000 gallons than for 200,000.

In nearly every case a minimum charge is made. This varies from 3s. to 15s. a quarter for the smallest size of meter, the difference being probably due rather to the circumstances and requirements of each individual water-works than to a divergence of opinion as to a proper amount. But, while too high a charge is unnecessary, there are two good reasons why it should not be too low. They are, that water required for trade purposes is almost invariably used in large quantities, and therefore a moderately high minimum is still likely to be much below the quantity actually taken; and next, as has been before pointed out, a meter is more liable to deterioration when

Minimum charges for water by meter for trade purposes.

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doing little or no work than when passing a considerable quantity. Hence the propriety of compensating the supplier for the risk thus incurred, by a fairly high minimum charge for water.

It is not the general practice to regulate this minimum by the size of the meter, but it is nevertheless submitted that this is the right course to pursue. It must be admitted that, granting the pertinence of the last-mentioned reason for a minimum charge, a large meter needs covering by a larger minimum than a small meter, because the damage it may sustain through insufficient work would entail a greater expense in repairing.

The following are suggested as average minimum charges for water supplied by meter for trade purposes :—

Size of Meter.	Minimum Charge per Quarter. £ s. d.
⅝-inch	0 10 0
½ „	0 15 0
¾ „	1 0 0
1 „	1 5 0
1½ „	1 10 0
2 „	2 0 0
3 „	2 10 0

In some places the minimum charge is considerably higher and calculated at a sufficiently high rate per thousand gallons to cover all expenses in connection with the meter, for which no additional rent or maintenance-charge is then made. The minimum charge covers all. The simplicity of this method doubtless has much to commend it both to supplier and consumer.

On the next page will be found the names of a few of the principal waterworks and the corresponding charges at each for water when supplied by quantity for Trade Purposes.

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Name of Town or Waterworks.	Price of water by Meter per 1000 gallons for Trade Purposes.			Charges by Meter for Trade Purposes.
	d.		s. d.	
Ashton-under-Lyne	10	to	1 8	
Birkenhead	8	„	1 3	
Birmingham	6	„	1 4	
Blackburn	6	„	2 0	
Bolton	6	„	0 9	
Bradford	3½	„	1 3	
Brighton	7	„	1 3	
Bristol	8	„	1 0	
Cardiff	6	„	1 6	
Derby	4½	„	0 10	
Dublin	6	„	—	
Edinburgh	6	„	—	
Exeter	9	„	1 6	
Glasgow	4	„	—	
Halifax	6	„	0 8	
Huddersfield	7	„	0 7	
Hull	6	„	0 9	
Lancaster	6	„	1 0	
Leeds	6	„	—	
Leicester	5	„	1 0	
Liverpool	7	„	0 9	
London—				
Chelsea Company	6	„	1 0	
East London	6	„	0 9	
Grand Junction	6	„	0 9	
Kent	10	„	0 10	
Lambeth	By agreement			
New River	6	to	0 7½	
Southwark and Vauxhall ...	6	„	0 9	
West Middlesex	6	„	0 9	

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Name of Town or Waterworks.	Price of water by Meter per 1000 gallons for Trade Purposes.		
	d.		s. d.
Manchester	4·85	to	2 0
Newcastle	5	„	1 2
Nottingham	6	„	1 0
Oldham	6	„	1 9
Portsmouth	8	„	1 6
Reading	6	„	2 0
Sheffield	6	„	1 0½
South Staffordshire	3	„	1 4
Southampton	6	„	0 6
Stockton-on-Tees Middlesboro' }	3	„	1 6
Swansea	6	„	1 2¾

There is a peculiarity about the system of charging by meter adopted at Sheffield, which is, so far as the writer is aware, unique. It is this: The charge for water supplied through a high pressure meter is 25 per cent. higher than that supplied through a low-pressure. The water is supplied from the same main in either case.

There are so few waterworks in England supplying water by meter for Domestic Purposes, that it is difficult to compare the charges with those for trade purposes. There are, however, the following:—

Charges by Meter for Domestic Purposes.

Name of Town or Waterworks.	Price of water by Meter per 1000 gallons for Domestic Purposes.
	s. d.
Abingdon	1 0
Malvern	1 0
Matlock Bath	2 0
Sowerby Bridge	1 0

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The number of meters that one meter-reader or inspector can read in a day is a question that is sometimes raised in reference to the internal economy of a waterworks.

Meter-Readers.

It is of course impossible to lay down any rule as to the number of meters one man should read in a day, as the circumstances of no two cases are alike, but the writer was told by the manager of a certain English waterworks that in his town there are 1200 meters which are all read every week; the whole of the work being done by two men. That is, each man reads 100 meters a day.

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CHAPTER VIII.

SHOULD THE WATER METER BE OWNED BY THE SUPPLIER OR BY THE CONSUMER?

Meters should be owned by supplier.

THE question whether the water-meter should be the property of the supplier or of the consumer is yet another point upon which there has been a wide divergence of opinion and practice. Although the general consensus is now decidedly in favour of the ownership being vested in the supplier, there are still those who contend that it would more fitly rest with the consumer. It is, however, no easy matter to discover the reasons upon which their contention is based, as none are apparent but which afford, when investigated, good ground for the contrary conclusion.

It is sometimes given as a reason in favour of the meter being owned by the consumer, that it would involve additional capital were the meter provided by the supplier. This argument would apply with equal force to the pumps or mains. All form part of the plant of a waterworks, and to be efficiently maintained should all be under the sole and absolute control of the water authority. Moreover where is the objection to increasing the capital? It cannot be said that it is not a dividend-earning investment of capital, because meter-rents are always so assessed that they yield a very good interest on the capital outlay.

Meters form part of plant of waterworks.

Consumer no prejudiced by this.

It evidently makes no difference as to payment, because the consumer must, in either case, pay for the use of the meter, whether directly if he buy it himself, or indirectly if

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not, through the price paid for water or as meter-rent, which must be high enough to recoup, or to pay interest on, the supplier's outlay for all materials and fittings used, in making the service.

Meter is supplier's ledger.

The meter acts as the supplier's ledger. It is, however, notorious that some meters are inaccurate. It would surely be unjust to allow the consumer to force on the supplier a false measure. But let it be assumed that this could be remedied by giving the supplier power to reject any meter that did not satisfy certain specified tests for sensitiveness and accuracy before fixing; the question of maintenance has then to be dealt with.

This anomalous and absurd position is reached: the supplier has to keep, or cause to be kept, the consumer's property in efficient repair, in order that he may receive proper payment for the water supplied, or to use a homely adage, the supplier has "to measure his corn with another man's bushel."

Meters out of repair always under-register.

Now, if when a meter got out of order it was as likely to register against the consumer as in his favour, it might be said that the average result would possibly be equitable; although that of course would be no argument in favour of the continued use of faulty meters. It is, however, *absolutely certain* that in ninety-nine cases out of every hundred in which meters, through want of repair, register incorrectly, they favour the consumer at the expense of the supplier. Everyone who has had any experience with meters will concur that over-registration is of almost unique occurrence, while under-registration is but too common. Over-registration by a positive meter is a physical impossibility, and is in the highest degree improbable by an inferential. Deterioration in either almost surely means under-registration.

The evil of this method is therefore intensified.

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If consumer owns meter constant disputes involved.

If the supplier has power to take out, examine, and, if necessary, repair, at the expense of the consumer, any meter which he doubts, it is very clear that continual disputes will arise, as the interests involved are diametrically opposed. The consumer, content with the small registration, will be loth to pay an expense incurred with the express object of increasing his water bill, while the supplier cannot allow an instrument to continue to act as accountant which he believes deprives him of part of his just payment.

The supplier who allows the consumer to buy and maintain his own meter, also allows him, *ipso facto*, in most cases, to take much of his water for nothing.

Where tried found unprofitable.

The results of such a system are apt to be overlooked where the supply by meter is but a small fraction of the total supply, but the evil is none the less present. In waterworks where it has been extensively adopted—reference is here made to American cities only—it has been found unprofitable in the extreme, and a change to the method of ownership by the supplier declared necessary.

The advantages attaching to this alternative method are many and cogent.

Advantages of ownership by supplier.

The consumer is relieved of all trouble in maintaining the meter. He pays a stipulated sum per annum to cover everything, except damage by frost or fire, instead of running the risk of being called on at any time to incur a heavy expenditure in repairing or renewing the meter. If he no longer requires the meter it is not thrown on his hands.

The supplier is able to select the instrument that experience has shown to be best suited for the purpose to be served, which being interpreted means that he will be able to obtain registration of all the water supplied, instead of, in some instances, only about fifty per cent. of it.

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He is able to put into practice a systematic inspection, in order to maintain the instruments upon which his income depends in proper order to record his "takings." In fact, he has control over his own till. He is able to clear up at once any doubt as to correct registration by repairing or replacing the suspected meter, without causing any dispute with the consumer, as he is acting absolutely within his own rights.

METER-FREAKS.

There are certain isolated cases on record of registration by meters without any water being supplied from them.

It is a moot point whether this even can be deemed over-registration, because under the peculiar conditions water passes through the meter although none is supplied from it.

In each instance this was attributable to two circumstances, both of which must be present to produce this extraordinary phenomenon. These are an "air-cushion" on the outlet side of the meter, and a pulsating pressure on the inlet side. The effect is to cause a constant ebb and flow through the meter. In one instance a 3-inch inferential meter was fixed to a 3-inch rising main for fire hydrant purposes; it led off a 21 main, and was only 75 yards from the pumping engines of the waterworks. To the intense surprise of the consumer who knew no water had been used, the meter was found to be registering no less than 24,000 gallons per day. A thorough overhaul of every inch of the 3-inch main revealed no leak. The meter was then replaced by one of another inferential make, with the astonishing effect that the registration at once jumped to nearly 48,000 gallons per day!

Further investigation discovered the causes, although it was, and is, impossible to more than surmise the

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rationale of their precise action on the fan or turbine. It would naturally be thought that if the meter registered the forward flow due to the increased pressure from each stroke of the pump overcoming the yielding air-cushion formed at the top of the rising main, it would run backwards with the ebb. But such is not the case.

A similar occurrence with a two-cylinder piston meter is more easy of explanation. Here again the causes were the same—pulsation and air-cushion on a rising main on the outlet of the meter—but the register of this meter was actuated by a reciprocating arm working between collars or tappets on one of the piston-rods. The ebb and flow kept the piston moving far enough up and down the cylinder to actuate the register at each stroke. This explanation is given by the engineer who had charge of the district in which this meter was fixed, and is no doubt quite correct.

It might, however, happen with reciprocating-piston meters of other types when subject to the same conditions, that the flow of the water would be registered but not the ebb. The reason being that while the flow actuated the meter in the usual way, the ebb, pressing on the under side of the D-valves, would probably lift them from the faces of the ports and pass quietly back through the meter without operating it. The next flow would bring the valves back to the port-faces, and make the meter register again, and so on.

The cure for this meter-freak is an air-valve placed at the top of the rising main—without an air-cushion there can be no ebb and flow. Or a reflux-valve may be fixed on the service pipe with equally good effect.

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CHAPTER IX.

THE ECONOMICS OF WATER SUPPLY CONSIDERED IN RELATION TO THE METHOD OF PAYMENT.

WATER METERS *VERSUS* WATER RATES.

Water-supply of London and other towns becoming insufficient.

THE water supply to the great cities of the United Kingdom has, during the last few years, constantly attracted public attention. One town after another has found itself faced by difficulties consequent on the demand exceeding the supply. Enormous sums have been expended and monster works constructed to provide for pressing needs. To-day a Royal Commission sits to consider the adequacy of the water-supply of the Metropolis itself; although, twenty-one years ago, a similar commission reported that the existing supply was sufficient for all time.

Economical means of meeting difficulties.

The purpose of this chapter is to call attention to a means whereby such difficulties, whether present or prospective, may be promptly and economically overcome. Hitherto the method principally employed has been to increase the supply, whereas the proper remedy in nine cases out of ten is the reduction of the demand. This can only be accomplished by preventing the prevalent waste and abuse of the commodity. Something has been done in this direction by various systems of inspection of fittings, and by other means. These efforts are, however, often nullified by causes which are for the most part beyond the control of the water authorities. Hence it is,

Prevention of waste.

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despite all that has been done in London, for example, that the consumption per head remains practically where it was twenty years ago, *i.e.*, about ten gallons per head per day more than the consensus of expert opinion considers necessary. Better results have been obtained—for a time at least—in some few smaller cities. But the only permanent and efficacious way of reducing the consumption per head to its proper quantity, and of economically restoring the equilibrium between supply and demand, is the universal adoption of payment according to quantity used. This assertion is not based on mere theory, but is supported by the experience of waterworks engineers in all quarters of the globe.

Payment by quantity only efficient method

It is proposed in the following pages to consider the question of payment for water according to the quantity consumed—*i.e.*, payment by meter—*versus* payment by rate, viz., by an assessed charge without regard to the quantity consumed. After dealing with the theoretical aspect of the matter, the practical side will be discussed from the point of view of its application to London. This not only has the advantage of being of particular interest at the moment, but, as the Metropolis embodies, in an acute degree, all the conditions and difficulties presented by other towns in the kingdom, to deal with it is to deal with all.

Main principle.

That, as an abstract principle, water, as much as any other commodity, should be paid for in absolute proportion to the quantity or value received, can be denied by no open mind. Subject to an apparent exception—one of expediency—presently to be noted, this rule can be shown to hold good too in its practical application.

In advocating a change from a system, which is notoriously the cause of dissatisfaction and dispute

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between supplier and consumer, to one which has been tried with very satisfying results, it will be opportune to consider the arguments for and against the change, and some of the results actually realized in places where it has been already made.

It has been said, but will hardly be accepted, except by those who think all necessaries should be gratuitous, that water should be as free as air. Evidently this is utterly fallacious, so long as cost attaches at the outset to the procuring of the one and not of the other. If, therefore, it be admitted that payment should be made, the question then is, What payment? In all else the unhesitating answer would be, For the value received. Then surely the more necessary the article supplied the greater the reason for selling it at this market value. Yet, for scores of years in London and elsewhere, water has been sold on the unjust and unprofitable rating system, although it has been proved again and again in other cities, that a great advantage is secured not only to the consumer, but also to the supplier by charging by meter. Bread is bought by quantity, but water by the position and size of the house of the purchaser, instead of by the quantity he receives. A householder buys just as much bread as his family requires, regardless of the size of his house; but be his family two or ten, he is compelled to pay an amount for water rated on the style of his dwelling, whatever quantity he may consume—50 gallons a day or 500. Yet water is as necessary as bread, and both are provided for the consumer by the capital and labour expended by the supplier. Should not the payment therefore be in the direct ratio of the value received?

Payment should be for value received, *i.e.*, by quantity.

The advantages of meter-supply have been proved practically.

It is evident that any system of charging not based on the quantity actually used must be an average and arbitrary

Evils of Rating System.

Arbitrary;

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Unjust;

one, and therefore injustice must be done to some, be they few or many. The consumer should pay for what he gets, but he also should get what he pays for. Under the present system he often does neither. In the first place it occurs in thousands of instances in London alone that consumers, either through thoughtlessness or from that wanton pleasure that some people unfortunately take in wasting the property of others, allow their water fittings to get into a very bad and leaky condition, and that taps and closets are kept constantly running, wasting perhaps a thousand gallons an hour. (Any waterworks engineer who has had night inspections made will corroborate this.) This is sometimes done with the mistaken idea of flushing the drains, by well-meaning people who would indignantly repudiate the charge of dishonestly using the water. Suppose this to happen in a house the water rate of which is 50s. per annum, representing a consumption of 50,000 gallons at 1s. a thousand gallons, which is about the rate at which the companies could afford to supply it by meter, with constant supply. The waste under the above conditions often amounts to at least 500 gallons an hour, which if continuing for ten hours only, during the night, would represent 35,000 gallons per week or 1,820,000 per annum, entailing £91 loss on the company. This may seem an extreme case, but such have happened and are happening in almost every waterworks in the kingdom. No doubt wherever there is a good system of inspection such cases would not be allowed to go for a year undetected, but although some may be stopped others are beginning.

Wasteful.

Example of waste.

Much of the consumption practically unpaid for.

In many such cases it is certain that the consumer does not pay a tithe of the consumption. Moreover, fittings deteriorate, however vigilant the company's inspectors, and the consequent waste most frequently escapes the

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house occupier's notice, as his servants have no interest in the matter, and he does not see the leaking taps, and thus does not, even were he so disposed, stop the waste; whereas, were meters used, his quarterly bill would at once draw attention to the increased consumption and the cause thereof. Here also much of the consumption is unpaid for. In like manner many other instances could be given, but they are only too familiar already to waterworks engineers.

On the other hand a great majority of consumers (for domestic purposes), paying water-rates on middle-class private houses, obtain a very poor return for their money.

On the other hand many consumers obtain a very poor return for their money.

London waterworks authorities would not contend that the rate per thousand gallons, if meter-supply were universal, should be less than 1s. This amount has indeed already been named. If the effect of metering were to save one-third of the present quantity pumped, this higher price received per 1000 gallons would bring the total revenues of the London companies to the same amount as they at present obtain. Now, as large quantities are being supplied by meter for trade purposes at 6d. per thousand gallons, it is evident that a large amount must be taken at a rate equivalent to considerably more than 8d. per thousand gallons, which is about the average price at present received for the whole quantity pumped, in order to bring the whole up to the average.

Those who pay this higher rate are they whose households are much smaller than their houses would accommodate. Many of these households consist of a man and his wife and one servant. As the middle-class forms a very large proportion of the water rate-paying population, let it be supposed that such a family are living in a house of the "net annual value" of £60, with two w.c.'s and a bath; the water rate would work out—

Example of over-payment.

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	£	s.	d.
4 per cent. on £60	2	8	0
2 w.c.'s at 6s., 3s.	0	9	0
1 bath at 6s.	0	6	0
High service, 10ft. above road ...	0	6	0
Total	£3	9	0

The consumption of such a family often would not at the outside exceed 15 gallons per head per day. [It must be remembered that the 31 gallons per head of population sent into London daily, covers the vast quantity wasted, and also that used for municipal, parochial, and trade purposes.] Fifteen gallons each for three people=45 per day, or 16,425 gallons per annum, at 1s. per thousand=16s. 6d. But as £3 9s. is actually paid for these 16,425 gallons of water the householder is thus charged the enormous price of 4s. 2d. per thousand gallons.

It is quite true that next door there may be a family of a dozen, all of whom use water liberally; but limiting them to the same quantity per head they still get 65,000 gallons for the £3 9s., or at the rate of 1s. 0¾d. per thousand gallons.

Given two men, each occupying, with their families, precisely similar houses at the same rent, why should one of them pay for washing the other man's children? Why should domestic supply pay for water used for trade purposes, and why should the small householder pay part of the brewers' water bill? Yet, at present, this is the universal custom in London.

In England the consumer, in America the supplier, demands meter system.

English and American opinions as to the effect of supply by meter are diametrically opposed. In England it is the consumer who is agitating for supply by meter and the supplier who refuses it; while our transatlantic

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cousins object to take their water by meter in lieu of the rating system to which they have been accustomed; nevertheless when the change has once been effected they quickly appreciate the equity of the new method.

Again, English engineers, as a rule, oppose meter-supply for domestic purposes, sometimes on sanitary grounds, but more often for the alleged reason that the revenues of the suppliers would be reduced without a corresponding economy being effected. The American profession, on the other hand, has adopted meter-supply in town after town, because the inordinate waste of water—which seems inseparable from the rating system—prevented the works from being remunerative, and caused so heavy a strain on their mains and pumping-plant that a radical change was imperative either in the quantity consumed and wasted, or else in the quantity supplied. The proportion of towns already metered is still comparatively small, but in view of the results obtained will no doubt rapidly increase.

Cause and effect of metering in America.

The results obtained have in all cases proved eminently satisfactory, for not only has the consumption been thus brought within proper limits, and further and unnecessary expenditure on new reservoirs and pumps been avoided, but the revenues of the suppliers have been increased, and this without any difficulties arising with the consumers, as none can object to pay for that which they have indisputably had. The actual figures obtained in three of these instances will be found a few pages later.

It is difficult to find any adequate cause to which to ascribe these curious differences of opinion, but as there are now estimated to be not less than 300,000 meters at work in the United States, it must at least be conceded that American engineers have a wider basis of experience on which to found their conclusions than have engineers

Possible causes of difference of opinion between American and English engineers.

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in England, where the use of meters is far more restricted. The latter often bring forward as an argument against meter supply that there is no *perfect* meter, which must at once be granted; but if the existing instruments are put to the purposes for which they are best adapted, there is now available an *efficient* meter for *every* purpose. (See page 54).

Perhaps one cause for the attitude adopted by American engineers is that better results are given by the rotary-positive class of meter, which is that generally used by them, when put to all-round purposes, than are obtained from inferential and even reciprocating piston meters, which until recently have been generally used in England, when put indiscriminately to every description of work.

Advantages to the consumer of meter supply.

The advantages of supply by meter from the consumers' point of view may be briefly summed up as follows:

All consumers have equal privileges at the same cost. No more water is paid for than is used, and that at the fair market price. No consumer has virtually to pay part of his neighbour's water rate as at present. The annoyance caused by inspections for waste is obviated. The consumer is not harassed by being arbitrarily called upon to fix new fittings of a particular pattern, as is at present necessary for the supplier's protection.

Advantages to the supplier.

On the supplier's side the benefits attaching to supply by meter are even greater. Waste, so far as the consumer is concerned, is stopped without even the trouble of inspection. The dividend-earning power of the capital employed is greatly increased, because all the work done by the pumps and other plant represents actual and remunerative consumption, instead of being in great part expended on waste of water from which no return is obtainable.

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Meters are infinitely better inspectors than any men. The latter can only—and often after prolonged and expensive search—detect waste, and then take measures to prevent its recurrence, the whole of the quantity wasted up to the time of detection being totally lost to the supplier. Meters, on the contrary, not only detect waste the moment it occurs, but charge it to the consumer who is responsible for it. Moreover this great saving to the supplier is effected without any trouble either to him or to the consumer.

Meter-supply often obviates the necessity for more reservoirs and pumping-plant.

The draught on the mains being confined to its proper limits, the pressure can be uniformly maintained at its proper standard. The saving in coal effected by the reduction of pumping to waste, as at present, is but a small part of the actual saving, as it carries with it wear and tear of plant of all descriptions, and the labour incidental thereto.

In fine, revenues would be increased and expenses diminished.

Water-waste in London necessitating additional supplies.

It has been estimated that of the 31 gallons per head per day pumped into London,* less than two-thirds is actually used, the balance of waste being divided between the suppliers' mains, etc., and the consumers' fittings, and deliberate waste. Even if this is assumed to be a large over-estimation, still we are pouring yearly at least a quarter of a million sterling down the gutter in water wasted. The consequence is that the question of new sources of supply is already mooted. If these are obtained, and no measures are

* Various good authorities have estimated the waste as "one-half," "one-third," "not less than one-third." See reports of various experts and Stevenson and Burstall, "Metropolitan Water Supply."

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taken to prevent the existing waste, the process will only amount to temporizing, which must have an end, and that in the near future. It must not be forgotten that the harm wrought by waste of water is not confined to considerations solely affecting the waterworks. Almost without exception, all water wasted passes into the sewers, and has to be pumped and otherwise dealt with as sewage. We have to pay, therefore, not only for obtaining double the necessary quantity of water in the first instance, but also for disposing of double the quantity of liquid sewage in consequence.

The provision of Constant Supply, now becoming universal, has largely increased the facilities for waste, which should be checked—or paid for. Metering accomplishes the former by threatening the latter, and is the necessary corollary to Constant Supply.

The Liverpool water supply.

Already Manchester brings its supply from Windermere; Glasgow from Loch Katrine; and Liverpool from Vyrnwy. In the last instance, the additional supply, declared urgently and immediately wanted eighteen years ago, has been rendered unnecessary until now, although the population has increased 172,000 in the meantime, by the prevention of part of the waste by means of Mr. Deacon's waste-water meter. Had the balance of the waste that arises through the consumer's negligence as to the state of his fittings, which now goes on until detected by the Corporation Waterworks' inspectors; and through the careless or intentional misuse of water—had this balance been also stopped, it is probable that this further supply, costing about two millions sterling, would never have been necessary. This waste can only be stopped by giving the consumer a direct interest in so doing, which is done if he pays by meter.

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Estimate of water-waste in America.

An American engineer of wide experience, a member of the American Waterworks Association, calculates loss by waste in the United States, from all causes, at 66 per cent. of the total quantity of water sent into the mains. This is in excess of the estimated loss in England.

There are in South America and elsewhere many towns where the whole supply is by meter, the cogent reason for the adoption of that method of payment being the scarcity and consequent high price of water, which does not admit of waste either from the supplier's or from the consumer's standpoint. In many of the larger Continental cities including Paris, Berlin, and Vienna,* meters have superseded rates for that reason, and in no case has the public health suffered because of the smaller consumption of water. If, then, this system is found not only efficient but necessary in such cases, why is it not equally reliable and desirable where water is cheap? Waste may be *tolerated* where there is abundance, but it is hardly business-like, and in London has brought us to the end of our tether.

Meters superseding rates in Continental capitals.

The use of meter by the London Hydraulic Power Company.

A striking instance of the efficacy and advantage of supply by meter is furnished by the London Hydraulic Power Company, who supply all their consumers by meter, and have had the satisfaction during the last two years of registering and of receiving payment for no less than 96 per cent. of the total water pumped.† Considering the fact that this water is delivered at a

* A paper was recently read by Mr. Gill, of the Berlin Waterworks, showing the excellent results achieved by the adoption of supply by meter. Previous to which the supply, when given on the rating system, had proved quite inadequate.

The Parisian Authorities have just decided to extend the meter system over their whole district of supply, as in no other way can they cope with the demand.

† The figures given by the Chairman of the Company, in his speech to the shareholders, on March 4th, 1891, are 1888, 95·45; 1889, 96·76.

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pressure of 750 lbs. per square inch, this is an engineering achievement of no mean order, and reflects the highest credit both upon the conception and upon the carrying out of the work.

The testimony thus adduced to the possibility of charging by meter under circumstances of so great difficulty is a strong *à fortiori* argument for the practicability of the method for ordinary waterworks purposes of all kinds.

Estimated cost of bringing new supply to London.

Before incurring the expense—which has been estimated at about £20,000,000—of bringing a new supply into London, it might be advisable to consider the probable effect of spending about *one-seventh of that sum in properly utilising the supply already available.* It is submitted that this could be done by substituting the present rating system by supply by meter, and by stopping or minimising the waste on the suppliers' mains by the general adoption of waste-water meters.

Adoption of meter supply advisable instead.

Probable effect and saving if this were done.

The beneficial effect of this alternative would not be confined to the £17,000,000 saved, but would be perceptible in the improved quality of the water itself; filtration would be more efficiently, because more slowly, effected. Also, the reduction of the draught on the Thames would have a distinctly purifying effect on the lower part of the river, which it needs not a little.

Effect on sanitation.

It has been declared that sanitation would be endangered were supply by meter to become general. Whatever danger may appear at the first glance will vanish if one looks more deeply into the matter.

Waste is not a concomitant of cleanliness, but economy often is.

The poor.

It is said that too little water will be used by the poor if it is paid for by quantity. What are the facts? We have under any system the "great unwashed," who,

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so far as personal cleanliness is concerned could not possibly *use* less water however it were sold. The amount of water required for house-sewage purposes is practically beyond their control. And both these people and those of the artizan class who live in model lodging houses, tenements, or apartments have but an indirect interest in the price of water. It is included like other taxes in the rent they pay to their landlord. The other portion of the artizan class and the lower middle class, including very small shopkeepers, would have greater reason for economy in water than either those below or those above them in the social scale. Of these the vast majority are too wise to forego the cheap luxury of cleanliness, and to risk the dangers to health which would be brought about by unduly stinting the use of water.

Sanitary minimum.

But even granting that this dangerous disposition did exist it would be easily met by a small minimum charge, based preferably on the number of occupants of each house. This would safeguard the public health from this source of danger, and yet should be so light a tax that the cost of the *proper minimum* consumption of the smallest household should not be exceeded. A high minimum would be undesirable because the benefits of meter supply would be lessened by the amount of the margin of waste thus provided in some cases.

It has even been contended that a minimum charge is not needed. Without debating this point there is no doubt that a *low* minimum tends to assist sanitation and to secure the remuneration of the supplier without causing any loss or hardship to the consumer, and it should, therefore, be embodied as one of the conditions of any scheme for the supply of water by meter for domestic purposes.

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In London and other large towns in England adoption of sliding scale for the poorest classes advocated.

Undoubtedly, the method of procedure with regard to the poorest classes, requires much consideration. Before proceeding to suggest a way to deal with the question, it will be well to point out the policy of making, in their favour, the exception to the principle of payment in absolute proportion to the quantity used, which was referred to previously. To carry out this principle in its integrity, necessarily involves charging the same price per thousand gallons throughout all districts, and to propose a lowering of price on a sliding-scale, for the less favoured districts and houses, seems a deviation from rule. But the requirements of sanitation supply one reason why this is politic. For similar areas, the drains receive more sewage in a poor crowded district than in a wealthy one. More water is needed to flush and cleanse these sewers. It would press hardly on the impoverished, had they to bear all the burden. The health and welfare of the community concerns all, both rich and poor. It directly benefits the well-to-do classes, that the poor are sanitarily sound. Therefore, by the adoption of a sliding-scale, let the rich provide a portion of the cost of this cleansing of sewers, as they do of the cost of making and maintaining the sewer-fabric in the poor districts. They thus would contribute towards the well-being of the community at large, and so indirectly would receive value for their money. The original principle would thus remain virtually intact. It may be asked if, in towns on the Continent and other parts of the world, the charge is the same for all classes, why adopt a sliding scale for London? The reason for the difference is this: In the former, owing to the desire to confine the cities within their fortifications or walls, the lower classes dwell chiefly in many-storied houses, in which the drain-pipes and connections are short, and easily cleansed without much expense in water. (A

Reason for reducing price to poor.

Sliding-scale benefits rich as well as poor.

In foreign towns no sliding-scale.

Reason of this.

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well-known English engineer once described these towering and crowded buildings, as "streets on end"). In London, are miles of streets of poor dwellings containing three or four rooms each. This entails miles of drains, etc., and large quantities of water to cleanse them. London as a city is unique, and the number of its lower orders unparalleled. Hence, exceptional measures must be taken to meet exceptional contingencies. Leaving, for the moment, the question of the price to be paid per thousand gallons, consideration must be given to another point which has been urged as an obstacle to universal metering. This is the cost of the meter itself. Here again, our mode of living causes the difficulty. In Continental cities, the sixty or seventy inhabitants per dwelling divide the cost of the meter which, with us, must be divided between seven persons (7·4) only — such being the average number of occupants per house in London.

Cost of measuring machine.

The cost of the meter, which includes interest on capital, amortisation of first cost, repairs and inspection, must be discharged by the consumer, either as meter rent, or as part of the price paid per thousand gallons for water consumed. The annual charge for meters suitable for small houses may be taken at from 6s. to 9s.

Meter rent.

Now it is obvious that as there are in London alone tens of thousands of houses, the water rates of which now do not exceed 10s. each, such a meter rent cannot be imposed in addition without unduly increasing their present payments. Keeping in view the assumed object of charging the poor no more for a proper and sufficient quantity, taken under the meter system, than they now pay by rate for any quantity they use or waste, a meter rent is prohibitive. It is, therefore, necessary to adopt the plan of merging the meter rent into the price paid for water,

Sliding-scale should be extended to meter-rent, and one payment should cover both cost of water and of meter.

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and of making the price so low that the cost up to the sanitary minimum will not exceed the present water rate. This means make the rich pay for the poor—which is the assumed desideratum. Clearly any departure from the rigid application of this principle, in favour of the equalisation of actual payment, tends to remove the only theoretical obstacle in the way of payment by measure. But it is preferable to suggest a solution of the question in its most difficult phase.

Practical illustration of sliding-scale.

In illustration of the views here advanced, suppose the following sliding scale were adopted:—

Houses or tenements having a net annual value of:—	Charge per thousand gallons up to a sanitary minimum for water supplied by Meter. Charge to include Meter rent.	Charge per thousand gallons supplied in excess of the sanitary minimum.
Under £10	5d.	1s. 2d.
£10 to £20	7d.	1s. 2d.
£20 to £30	11d.	1s. 2d.
Above £30	1s. 2d.	1s. 2d.

Sanitary minimum to be ten gallons per head per day.*

It will be found that on the above scale the charge for water by meter, up to the sanitary minimum, would be about the same for a household of seven persons—the average number of inhabitants per house in London—as the charge under the present rating system.

It is suggested in the above table that when the consumption exceeds the sanitary minimum all should pay alike—for water then ceases to be a necessity; it becomes a luxury.

It may be objected to the above suggestion that the principle advocated of embodying the meter rent in the price of water aggravates the present inequality of payment

* Waste preventers or flushing tanks should be compulsory, in order to secure the more thorough cleansing of the drain-pipes and sewers.

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because not only is the poor man to get his water for as small a payment as of old but also is to have a meter for nothing. This would be true but for two facts:—First, many of the poor now get their water *much* cheaper than is apparent; for they pay a very low rate—say 10s.—and obtain in return—owing to the way they waste and abuse it—much more water than is their due. In confirmation of this, actual experiments have proved that while some well-to-do people are paying at the rate of 4s. per thousand gallons, others—poor ones—are getting all they take—and far more than they need—for one penny per thousand gallons of collected, impounded, filtered, pumped and delivered water. More than four tons of water for a penny! Surely this is going a little too far in helping the poor. In the next place, not all the poor will confine themselves to the sanitary minimum; many can afford, and will take, some water at the price paid by the rich. Part of the better price obtained in these two ways for water supplied by meter may fairly be considered as meter rental.

So the old and new systems considered solely in relation to a poor district would compare as follows:— Table giving comparison of systems.

	Amount paid per annum for Water for the Poorest Class of Dwellings.	Price per thousand Gallons consumed in a Poor District.
Old system —By rate.—	10s.	From 1d. to 8d.
New system —By meter.—	10s. plus amount for water used in excess of the sanitary minimum.	5d.; and 1s. 2d. for quantity consumed in excess of the sanitary minimum.

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It is submitted that the foregoing suggestions afford at least a basis on which to build a practicable scheme for the adoption of supply of water by meter for domestic and all other purposes.

The sort of "legalized state socialism" involved in the rating system which cheapens water to the poorer classes at the expense of the well-to-do, and which its advocates aver is its chief merit, is retained in the above method of supply by meter.

At the same time the abominable waste now prevalent—particularly in the dwellings of the poor—is permanently cured. No inspections, no stamped regulation fittings can do more than alleviate the evil! The meter system eradicates it.

Exceptions after all but limited.

Much has been said herein about the exception to the principle enunciated in the beginning of this chapter, of all paying alike, but it must be remembered that the class in whose favour this is made forms after all only the minority of the consumers. All consumers in the same stratum of society—judged by house rent—and all consumers of any, and every, rank above £30 "raters" pay equally, in proportion to value received.

Now to assess the cost to the present consumers of supply by meter. Let it be assumed that, in order to continue to the water companies the same aggregate revenue that they now enjoy, the price of water per thousand gallons should average 1s., and that the cost of providing and fixing meters would be amply covered by £3,000,000.

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Cost of metering present supplies.

This would give—

Interest at 4 per cent. per annum	...	£120,000
Amortisation, 3 per cent. per annum	...	90,000
Repairing, 3 per cent. per annum	...	90,000
Inspecting...		10,000
		310,000
Less economy effected by one-third less pumping and other expenses incidental to the quantity of water pumped	...	90,000
Balance, being the net annual cost of metering		£220,000

This amount would be approximately equivalent to 1¼d. per 1000 gallons supplied, which, with the proposed charge for the water, would give a total average rate of 1s. 1¼d. per 1000 gallons. The water saved—say, 60,000,000 gallons per day—would then be available for an increased population of 3,000,000.

It is true that at the present moment there is not actual need to incur this annual charge of £220,000, as the present supply distributed in the present manner is sufficient for the existing population. But it is admitted on all sides that something must be done, and done at once; for, whether it be a new supply of water, or the substitution of supply by meter in lieu of the rating system, it will take many years to carry into effect.

It seems impossible that London can continue to increase during the next two decades at the same rate it has done for the past two; this would mean adding to its already

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immense mass an extra population in itself equal to the whole of that of any other capital in the world. Still, until there are more evident signs of a change than at present, we can only estimate the future by the past. Water must be provided for the coming host, whom let us estimate at two million souls. Shall this be done by properly utilising the present ample supply, or by obtaining further supplies of water from new and distant sources? There are two points by which to weigh the merits of these alternative schemes—time and cost.

Length of time before further supplies available.

If we may judge from the experience of Manchester and Liverpool, and considering the distance the water would have to be brought, it would be at least fifteen years before a new supply could be available, while the need of it will probably be markedly felt before half that period has elapsed. Meters on the other hand, although it might be as long or even longer before every house could be metered, would exercise a beneficial effect from the very commencement of the application of the system. By dealing first with those districts or houses where most waste was suspected, a margin of water available for the supply of the advance guard of the new army of consumers would soon be provided, and the supply could be kept fully equal to the demand.

Meters at once provide further available supplies.

To properly consider the second point—cost—it is necessary to look forward to, say, the first decade in the twentieth century. Let it be supposed that the population has increased by two millions, and that their 250,000 new houses are supplied on the rating system by water brought from Wales. What will be the cost?

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Estimated cost of works to bring water from Wales to London	£20,000,000	
Interest on the above at 4 per cent. per annum		£800,000
Annual cost of maintenance of works, pumping, salaries, and other expenses incidental to new supply		550,000
		£1,350,000

N.B.—The extension of the present distributing mains and of all other expenses connected with the distribution to the new consumers are not included in these estimates, as these items would be the same under both systems.

As against these figures, those representing the cost of the meter system must be placed as follows:—

Cost of meters and fixing £1,000,000.	
Interest at 4 per cent. per annum on above sum	£40,000
Amortisation at 3 per cent. per annum	30,000
Repairing at 3 per cent.	30,000
Inspecting	5,000
	£105,000
Add estimated annual cost of metering all present supplies (see page 107)	310,000
	£415,000

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As the existing supplies, reservoirs, filter beds, pumping engines, &c., would be sufficient for an increased population of at least 3,000,000 no further capital expenditure would be necessary under these heads.

Comparison of respective costs.

The figures given above show that to provide a supply of water for a further population of 2,000,000 people would cost £1,350,000 per annum (plus cost of distributing mains, etc.), if supplied on the rating system as against £415,000 per annum (plus cost of distributing mains, etc.), if all London were supplied on the meter system. The saving effected by the latter would then be £935,000 annually.

No matter whether consideration be given to equity of payment, to the time that must elapse before water is available to supply an increased population, or to the cost of providing such further supply, it is demonstrated that on any and all points the advantage rests with the system of supply by meter.

Need for economising all supplies in view of great growth of population.

The argument may be used, in opposition to metering, that even if it so economises the present supply that it is available for the requirements of a further 3,000,000 consumers, yet at the present rate of the growth of London, fresh supplies will nevertheless be needed in forty years time. The ultimate size of London is a problem only to be solved by the future, but enough for the present purpose to reply that if it should continue to add to its already phenomenal proportions as of late, the necessity of economising to the utmost the present and all further supplies is much accentuated. All available sources and gathering-grounds would be requisitioned at fabulous cost, and yet the demand would exceed the supply. If, on the other hand, the population should not increase more than another million, or so, and then remain stationary, it will

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have been gratifying to have avoided an unnecessary expenditure of £15,000,000.

Reference has been made to the highly satisfactory results attained by the adoption of the meter system in various parts of the world. Some details are appended below of the precise effects of the change in certain towns in the United States.

The town of Flushing, U.S.A., under rating system.

The following facts referring to the town of Flushing, N.Y., were given by Mr. G. A. Roullier in a paper read at a meeting of the New England Waterworks Association:—

"Population 8000; system, direct pumping; works, four miles from town; connecting main, 12 inches in diameter; no manufacturing interests of consequence, the place being composed almost entirely of residences. In 1886 the consumption rose to 120 gallons per capita. With a pressure of 75 lbs. at the pumps only 35 lbs. could be maintained at the office during the hours of maximum consumption,—the two gauges being practically on the same level.

"In cold weather the consumption during the small hours of the night exceeded that during the hours of daylight. The lack of pressure was complained of throughout the place, and in many of the elevated points in the village the supply ceased altogether during the hours of maximum consumption.

Under meter system.

"As immediate action was necessary, metering was decided upon, in the face of the bitterest opposition. After considerable trouble 100 meters were set on those services where waste was supposed to be the greatest. The pressure at once rose from 35 lbs. to about 42 lbs., and the daily consumption per tap fell from 754 to 578 gallons.

"The benefits derived from these few meters were such

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that the system was extended, until in 1889 $46\frac{78}{100}$ per cent. of the taps were metered.

"During that year the MAXIMUM average daily consumption per tap was the same as the MINIMUM average daily consumption per tap of the year 1886, notwithstanding the fact that in 1889, 232 more services were in operation than in 1886. The annexed table will explain the benefits in detail.

Results of Metering at Flushing, U.S.A.

"To-day 620 meters are set, and with 70 lbs. at the pumps a pressure of 50 lbs. is readily maintained in the office, and ample service is furnished throughout the village. The coal consumption has been reduced 400 lbs. per day.

"On all metered premises the adjustment of complicated rates has been done away with. Disputes as to excessive use of water have ceased. The landlord gets the benefit of any vacancy that may occur in his premises. The consumers are charged according to what they use. The numerous inspections are of the past. *Simplicity and economy have taken the place of complication and wastefulness.*"

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TABLE SHOWING ECONOMY EFFECTED THROUGH THE ADOPTION OF THE METER SYSTEM AT THE FLUSHING WATERWORKS, U.S.A.

G. A. Roullier, Superintendent.

	1886.	1887.		1888.		1889.	
	The average consumption per tap for the preceding 10 months was 770 gallons per day, the percentage of taps metered being 72.	Average number of gallons used daily per tap.	Per cent. of taps metered.	Average number of gallons used daily per tap.	Per cent. of taps metered.	Average number of gallons used daily per tap.	Per cent. of taps metered.
January				588	15·41	521	19·73
February				586	15·75	574	20·38
March				581	15·75	522	22·43
April				523	15·81	460	33·71
May		584	9·41	509	16·47	481	39·45
June		578	12·11	561	16·82	478	42·62
July		570	12·88	587	16·74	487	44·83
August		534	13·34	583	17·01	454	45·62
September		509	13·88	508	17·27	445	45·85
October		460	14·85	490	18·33	416	46·20
November		472	15·16	404	18·78	416	46·68
December		496	15·43	516	19·26	410	46·78

The following statements and figures are taken from a paper read by Mr. C. B. Brush before the American Society of Civil Engineers. They are compiled with such evident care and accuracy that they can hardly fail to be of interest to all water engineers.

Hoboken, U.S.A.

On November 1st, 1882, Hoboken, N.J., with a population of about 33,600 people, had just had 16 miles of new

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water mains laid. For 25 years previously Hoboken had been supplied, under the house-rate system, by the water-works of Jersey City. When the new supply was turned on, the first six months' consumption showed a daily demand of nearly 4,000,000 gallons. Mr. Brush was convinced that one-half of this was simply waste, and he at once took prompt action to check it, without restricting the legitimate use of water. The result has been to save about 1,500,000 gallons per day, reducing the waste about equally on mains and that due to consumers.

Consumption under rating system.

Saving effected by metering.

The following table shows a comparison of the results obtained during the first six months of the first and fifth years of the new supply :—

	Six months from Nov. 1, 1882, to May 1, 1883.	Six months from Nov. 1, 1887, to May 1, 1888.
Population	33,000	41,000
Taps unmetered	2667	2648
Taps metered	47	822
Total Taps	2714	3470
Daily draft, United States gallons, unmetered...	3,471,645	2,022,843
" " " metered ...	459,099	945,975
Total	3,930,744	2,968,818

Mr. Brush does not charge this entire result to the attachment of meters, but to other precautions in addition. House-to-house inspections were made twice a year, as well as night inspections of the mains and service-pipes. The reduction of waste in service-pipes was, however, mainly due to meters, used where consumers were supposed to be most wasteful. This is given as not only the most effectual method of restricting consumers but of determining leakage from mains where metering is universal.

The pressure is now 25 per cent. higher on the mains than before this waste was checked.

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Mr. Brush then gives the following tables showing the effect on the company's receipts of the system which had saved them so much in expenditure.

Tables showing the actual effect of the attachment of meters during the fall of 1885 on 439 houses in Hoboken, previously supplied for many years on the house-rate system:—

Comparison of receipts under rating and under meter systems at Hoboken, U.S.A.

Number of Consumers' Accounts Reduced or Increased.	Former House Rates.	Present Meter Rates.	Difference.
Nov. 1, 1885, to Feb. 1, 1886.			
	Dols.	Dols.	Loss. Dols.
83 per cent. reduced	2978·39	2047·92	930·47
17 ,, increased	687·41	1042·73	355·32
	3665·80	3090·65	575·15
Feb. 1, 1886, to May 1, 1886.			Gain.
63 per cent. reduced	2382·13	1433·28	948·85
37 ,, increased	1424·87	2610·50	1185·53
	3807·00	4043·78	236·68
May 1, 1886, to Aug. 1, 1886.			
59 per cent. reduced	2254·88	1453·26	801·62
41 ,, increased	1566·95	2775·17	1208·22
	3821·83	4228·43	406·60
Aug. 1, 1886, to Nov. 1, 1886.			
57 per cent. reduced	2188·45	1447·16	741·29
43 ,, increased	1633·38	2813·29	1179·91
	3821·83	4260·45	438·62
Nov. 1, 1886, to Feb. 1, 1887.			
72 per cent. reduced	2751·72	1941·04	810·68
28 ,, increased	1070·11	1948·81	878·70
	3821·83	3889·85	68·02
Feb. 1, 1887, to May 1, 1887.			
			Loss.
75 per cent. reduced	2684·71	1606·88	1077·83
26 ,, increased	1025·35	1661·09	636·74
	3710·06	3267·97	441·09
May 1, 1887, to Aug. 1, 1887.			
			Gain.
58 per cent. reduced	2216·67	1558·00	658·67
42 ,, increased	1605·16	2737·72	1132·56
	3821·83	4295·72	473·89

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Number of Consumers' Accounts Reduced or Increased.	Former House Rates.	Present Meter Rates.	Difference.
Aug. 1, 1887, to Nov. 1, 1887.			
	Dols.	Dols.	Gain. Dols.
62 per cent. reduced	2431·26	1580·34	850·92
38 „ increased	1405·16	2450·48	1045·27
	3836·42	4030·77	194·35
Nov. 1, 1887, to Feb. 1, 1888.			
67 per cent. reduced	2477·78	1709·49	768·29
33 „ increased	1160·37	1981·67	821·30
	3638·15	3691·16	53·01
Feb. 1, 1888, to May 1, 1888.			
70 per cent. reduced	2650·14	1947·87	702·27
30 „ increased	1059·92	1833·83	773·91
	3710·06	3781·70	71·64

These results show a net increase of revenue of 925·57 dollars, to which must be added the amount represented by water saved. It is particularly to be noted that 66·6 per cent. or exactly two-thirds of the consumers pay less by meter than they did under the rating system, but yet the remaining consumers pay so much more under the meter system that the net result is an increase of nearly 1000 dols. paid for water. The same tendency was observed in the next experiment, in which, in order to ascertain the effect of the meter system in a new district, 191 average dwellings were selected connected with the high-service plant. Each dwelling contained about eight occupants. These houses were metered. If house rates in each case had been charged, the daily draft *per capita* would have been about 75 gals., and the following result would have been obtained: —

Houses.	Annual Revenue.	Daily Draft.
191	2,645·48 dols.	115,000 gals.

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The following have been the actual results :—

	Annual Revenue. Dols.	Daily Draft. Gals.
First six months, winter	1081·82	12,860
Second six months, summer	1617·26	18,942
Third six months, winter	1510·44	18,000
Fourth six months, summer	1859·94	24,000
Fifth six months, winter	1385·17	16,550
Sixth six months, summer	1959·24	23,000
Seventh six months, winter	1751·52	21,645
Eighth six months, summer	2083·84	25,387
Ninth six months, winter	1825·92	22,516

At house rates each house would have averaged 13·85 dols. per annum.

At meter rates the actual return was 9·56 dols. :—

	Dols. per annum.
At the rate of first six months, winter	5·66
,, ,, second ,, summer	8·46
,, ,, third ,, winter	7·90
,, ,, fourth ,, summer	9·74
,, ,, fifth ,, winter	7·58
,, ,, sixth ,, summer	10·25
,, ,, seventh ,, winter	9·16
,, ,, eighth ,, summer	10·91
,, ,, ninth ,, winter	9·56

Results of metering at Hoboken, U.S.A.

In this instance, therefore, the payment was 69·1 per cent. of the amount that would have been receivable under the rating system, but the water used was *only* 17·6 per cent. of that which would have been used under the rating system. So that more than two-thirds of the payment was obtained by the sale of less than one-fifth of the commodity. Not only, therefore, is the balance of gain in favour of the supplier, but the revenue is a steadily increasing one, so that gradually it would, as in the previous cases, exceed the amount obtainable by rate.

Each corresponding period shows a constantly increasing use of water. It will be noticed that in a metered district the draught in winter is less than in the summer. In unmetered districts the reverse is the case. During the extremes of cold and hot weather the draught *per capita*

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is about the same in both districts, but after the extreme weather has passed, the waste in the metered district immediately ceases, while in the unmetered district the waste continues for some time.

Mr. Brush refers at some length to the advantages to be obtained under the meter system by the detection of leakage in mains, as shown by difference between the total registration of consumers' meters and the quantity sent into the mains.

It will be seen from the following table that, during the latest quarter, 356 consumers, out of a total of 775, used less than 4 dols. worth of water per annum, and practically this proportion of small consumers appears in each of the nine quarters given. In order to check this economical tendency of some of the consumers in a new district, the company was obliged, during the year 1886, to establish a low minimum rate depending upon the size of the meter attached to the consumer's service pipe.

Classification of Consumers of the High Service District of the Hackensack Water Company, re-organised, according to Amounts Paid Annually previous to the establishment of a Minimum Rate. All the Consumers were Metered.

CLASSIFICATION.

AMOUNT OF WATER CONSUMED PER ANNUM.	No. OF CONSUMERS IN EACH CLASS ON QUARTER ENDING								
	Feb. 1886	Nov. 1885	Aug. 1885	May 1885	Feb. 1885	Nov. 1884	Aug. 1884	May 1884	Feb. 1884
Dols. Dols.									
Between 0 and 2	164	107	57	128	127	66	37	66	66
„ 2 „ 4	192	165	123	125	107	93	60	46	52
„ 4 „ 6	124	106	67	62	71	67	37	30	25
„ 6 „ 8	55	72	65	38	36	40	32	12	20
„ 8 „ 10	43	45	37	32	30	19	22	16	13
„ 10 „ 12	40	20	39	22	15	16	9	10	8
„ 12 „ 16	49	52	36	21	24	31	24	12	9
„ 16 „ 20	26	27	29	17	14	21	9	5	7
„ 20 „ 40	58	55	69	52	32	37	31	10	7
„ 40 „ 80	12	17	10	10	9	11	7	8	2
„ 80 „ 200	7	5	10	10	4	5	5	4	4
Over 200 dollars	5	5	6	5	5	4	4	3	3
TOTAL	775	676	548	522	474	410	277	222	216

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The result of the experience of this water company is that the meter system is mutually advantageous, both to the consumer and the company. Each metered consumer pays only for the water he uses, and there are no restrictions either as to quantity used or to the time of use. No inquisitorial examinations of premises, so unpleasant to consumers, are required. It is to the interest of each consumer to have good plumbing. Those who are careless and wasteful, and those who require or desire to use more than an average amount of water, must and should pay for such excess, but the balance, constituting *two-thirds of all the consumers, pay less by meter than by house rates.* Meters were attached only after intense and prolonged opposition. Common sense prevailed, however, and now they are quite popular.

Says Mr. Brush, "Perhaps the greatest folly of our time is the almost universal attempt of cities and towns to increase their water-supply plant to keep pace with their waste. It is a hopeless task. It amounts to the same thing as attempting to fill a pail which has only a sieve for a bottom. The amount of water that can be used is limited; the amount that can be wasted has no limit. The patience of man has a positive limit, and therefore any amount of water should not be considered as waste, if drawn from a self-closing cock held open by hand—drawn for sprinkling gardens, lawns, roads, side-walks and buildings, through a hose held in the hand—drawn for fountains or for use in the various forms of business —but certainly water leaking from street mains, service pipes and fixtures out of order, is useful to none, a damage to the individual consumer, and a serious tax on the community. Flushing pipes and drains from time to time is not waste; but allowing small streams of water to run continuously from partially open faucets and cheap water

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closets is waste of the most serious character, and if not continually watched and checked will soon reach alarming proportions."

Town of Atlanta, U.S.A. Benefits derived by substitution of meter in lieu of rating system.

Mr. Wm. G. Richards, Superintendent of the Atlanta Waterworks, writes as follows :—

"Our works are city property, and are used for almost any and all purposes for which the city can use water, such as puddling ditches after laying sewers or water mains, flushing sewers, and frequently for washing gutters, so that anything like a comparison of the pumping with the meter records would be an impossibility. Then, the public schools are not metered, the city claiming the right to use all the water they want.

"Meters were introduced here as an absolute necessity. The pumpage had become so great that, with our machinery, it was impossible to maintain a satisfactory pressure, and the city was not in a condition to put in more pumping machinery and a larger main. Meters have now been in general use here about three years, and the pumpage does not reach an average of 2,000,000, and before their general introduction it frequently reached 5,000,000 per day. Our number of consumers has regularly increased, but the waste is stopped, and the pressure is satisfactory all over the city."

Summary.

It may not be out of place to conclude this long chapter with an epitome of its argument and fact.

London and other large cities in Great Britain are feeling the need of further water supplies. That the number of "fresh fields and pastures new" is nearly exhausted is attested by the fact that the metropolis and one of the great Midland cities were recently competing for a water-shed some seventy miles distant from the one and over one hundred and fifty from the other.

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It is admitted by the great majority of water engineers, if not by all, that nearly one-half of the quantity now delivered into the mains is wasted. *That is, if all the water at present available were rightly used it would serve a population nearly double the number of that now existing.*

The same difficulty of supply and demand has been experienced in many of the large cities of Europe and of America. In every case the adoption of supply by meter has remedied the evil by preventing waste. Existing supplies have then proved more than adequate. The same measure would effect the same cure in Great Britain. This is admitted, even by opponents of the meter system. But it is contended that there are difficulties peculiar to our mode of life, that prohibit the adoption of supply by meter in this country. Chief among these is the undoubted fact that supply by meter would entail hardship on the poorest portion of the community *if they paid at the same rate per thousand gallons as the wealthier classes.* This objection can, by the introduction of a sliding scale of payment per thousand gallons, be easily obviated, and the same help can be extended to the poor when water is supplied by quantity as now is when it is supplied by rate.

The demands of sanitation and humanity can thus be satisfied, while the virtues of economy and carefulness are inculcated. Waste need no longer be tolerated merely because it occurs in a poor district. But if by a new supply wastefulness be rewarded by fresh gifts of things wasteable, it is but putting a premium on waste, and therefore discounting the adequacy of future new supplies.

Payment by quantity is the only known means of *permanently* reducing waste to its minimum. It surely cannot be to the interest of even the poor to permit the

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continued waste of a vital commodity, the end of the supply of which is within view.

Whether is it better to temporize, *i.e., at immense cost* seek fresh supplies that may suffice for some years? or at a seventh of that cost to effect a permanent and sufficient economy?

Granting that for sanitary and social reasons the poor must be relieved at the expense of the well-to-do, so that in either case the latter must "pay the piper" whether for new sources of supply or for the conservation of the old, the question is, *Will he prefer to pay £4 in order that he and the poor man may go on wasting water at will?* Or will he pay £1 and forego waste?

It is not necessary to more than refer as a last, but by no means least, point to the equity of payment secured by the meter system. Every one receives in direct proportion to what he pays instead of, as now by rate, either putting his hand into his neighbour's pocket, or groaning under a water rate that would suffice for a whole village in return for the privilege of washing his hands at his office.

The adoption of supply by meter will, in the immediate present, save the unnecessary expenditure of about £17,000,000. If after half a century the continued growth of the population should at last render necessary a further supply it can then be brought with much greater likelihood of being permanently useful and of being economically consumed; for the Nation of London would, owing to its meter education, have learned to appreciate, and not to abuse one of the chief of Nature's necessaries.

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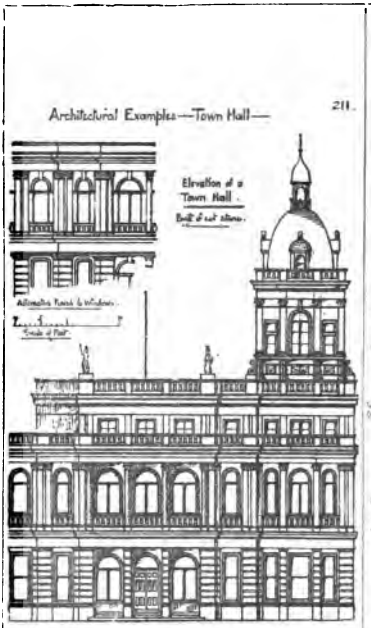

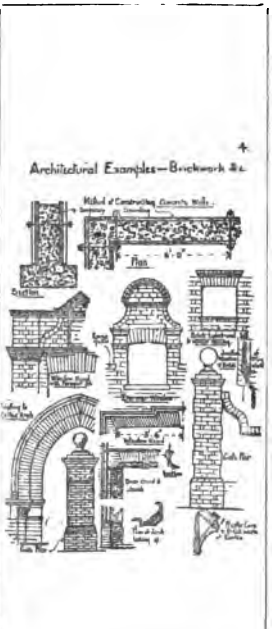

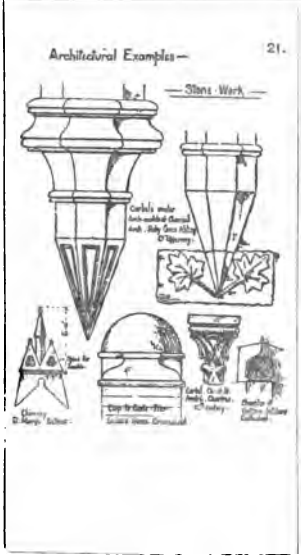

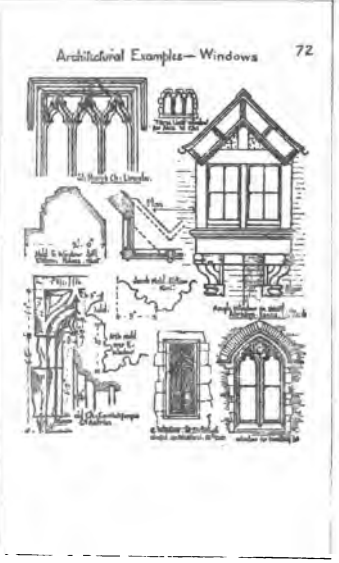

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Flax Machinery	47, 48
Float Water-wheels	48
Forging	48
Founding and Casting	48 to 50
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Fuze, 51; Gas	51
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Gearing Belt	10, 11
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Glass Machinery	53
Gold, 53, 54; Governor	54
Gravity, 54; Grindstone	54
Gun-carriage, 54; Gun Metal	54
Gunnery	54 to 56
Gunpowder	56
Gun Machinery	56, 57
Hand Tools	57, 58
Hanger, 58; Harbour	58
Haulage, 58, 59; Hinging	59
Hydraulics and Hydraulic Machinery	59 to 63
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India-rubber	63
Indicator	63 and 64
Injector	64
Iron	64 to 67
Iron Ship Building	67
Irrigation	67 and 68
Isomorphism, 68; Joints	68
Keels and Coal Shipping	68 and 69
Kiln, 69; Knitting Machine	69
Kyanising	69
Lamp, Safety	69, 70
Lead	70
Lifts, Hoists	70, 71
Lights, Buoys, Beacons	71 and 72
Limes, Mortars, and Cements	72
Locks and Lock Gates	72, 73
Locomotive	73
Machine Tools	73, 74
Manganese	74
Marine Engine	74 and 75
Materials of Construction	75 and 76
Measuring and Folding	76
Mechanical Movements	76, 77
Mercury, 77; Metallurgy	77
Meter	77, 78
Metric System	78
Mills	78, 79
Molecule, 79; Oblique Arch	79
Ores, 79, 80; Ovens	80
Over-shot Water-wheel	80, 81
Paper Machinery	81
Permanent Way	81, 82
Piles and Pile-driving	82 and 83
Pipes	83, 84
Planimeter	84
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Quarrying	85
Railway Engineering	85 and 86
Retaining Walls	86
Rivers, 86, 87; Rivetted Joint	87
Roads	87, 88
Roofs	88, 89
Rope-making Machinery	89
Scaffolding	89
Screw Engines	89, 90
Signals, 90; Silver	90, 91
Stationary Engine	91, 92
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